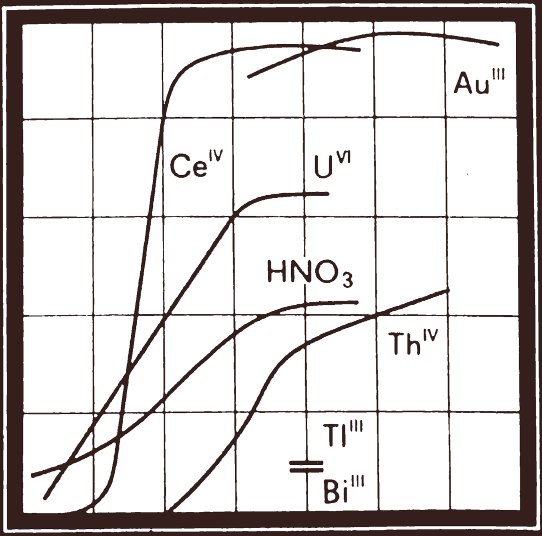
Ju. LURIE

Handbook of Analytical Chemistry



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TO THE READER

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Preface

Handbook of Analytical Chemistry is intended for scientific workers, and chemistry students in universities, polytechnics, and technical colleges. It can be used in solving various problems (both calculating and experimental) concerning general chemistry, analytical chemistry, chemical technology, and so forth.

The tables of solubility products, of ionization constants of weak acids and bases, and of oxidation-reduction potentials have been drawn up according to recent data. When those tables were being drawn up, the following works were used: J. Bjerrum, G. Schwarzenbach, L. G. Sillén, *Stability Constants of Metal-ion Complexes, with Solubility Products of Inorganic Substances*, London, 1958; W. M. Latimer, *The Oxidation States of the Elements and Their Potentials in Aqueous Solutions*, N.Y., 1952; N. V. Axelrud and Ya. A. Fialkov, *Ukrainskii khimicheskii zhurnal*, 16, 75, 283, 296 (1950), and other articles from Soviet and foreign journals.

As we know, the results published by various authors concerning the determination of given quantities greatly differ from one another. It is therefore extremely difficult to select the "most probable" value of every constant. There is no international body to annually publish such "most probable" values of the given constants, as is done, for instance, by the International Commission concerning atomic weights. The selection I have made from numerous literary data is therefore inevitably subjective. I will be very grateful for information pointing out cases when this selection was made incorrectly, and will take account of such comments in the subsequent publications of the book.

The tables of the densities and concentrations of various acids and bases are drawn up for 20 °C.

The temperature values in all tables are given in degrees Celsius (°C).

Tables 22, 32, 33, 34B, 35, 39, 47, 48, 51-55 have been compiled by P. K. Agasyan, docent of the analytical chemistry department of the Moscow State University.

Instead of the ordinary table of five-place logarithms, a "simplified" table of five-place logarithms and antilogarithms is given at the end of the book. It takes up the same space as the tables of four-place logarithms, because instead of the real values of the differences between mantissas, their mean values are given for every line of the table. Errors that arise when using this table are not over 0.00002. The other tables in the handbook give exact values of the five-place mantissas of logarithms.

Ju.Ju. Lurie

Preliminary Remarks

The numerical expression of the results of weighings and other measurements, and the subsequent calculations with these numbers necessitate a strict observance of several rules.

Rule 1. *All numerical values, whether they are obtained directly by measurements or whether they are the derivatives of these measurements, must have a certain number of significant digits so that the last figure alone is questionable; the second-last figure must be accurate.*

For instance, the number 20.24 (ml), which expresses the reading of an ordinary burette, contains a proper number of figures, since figure 4 was obtained by an approximate (visual) estimate of the distance between the edge of the meniscus and the nearest scale division. Consequently, this figure is dubious: another observer could read the measurement of the burette as 20.23 or 20.25 ml. If upon measuring the solution by a burette, the lower boundary of the meniscus exactly touches the scale division showing 15 ml, the measurement result must be expressed by the number 15.00 (ml), since the observation error is not over 0.01-0.02 ml. Both zeroes in the number 15.00 (ml) will be significant digits. The zeroes standing at the beginning of the number before the first figure which is not a zero are not regarded as significant digits. Hence, the number expressing the mass of the filter ash 0.00004 (g) contains only one significant digit: 4.

If the mass is determined in grams and expressed by the number 23.4 (g) in which the last figure is inaccurate, in order to represent this mass in milligrams one must write not 23 400 mg, which would give a wrong idea about the accuracy of the weighing, but $234 \cdot 10^2$ mg, or $2.34 \cdot 10^4$ mg.

Rule 2. *When discarding the last figure if it is equal to or more than 5, the preceding figure must be increased by unity.*

Thus, in discarding the last figure in the number 16.236, we obtain 16.24.

Rule 3. *Upon addition (and subtraction) of several numbers, there will remain, as a result of calculation, a certain number of figures after the point that are in the addend with the least number of decimals.*

Rule 4. *Upon multiplication or division, the maximum relative error of the product or quotient cannot be less than the relative error in the least accurate number from the numbers taken.*

Relative errors are usually expressed in per cent: it is the ratio of the maximum possible error of the number to the number itself multiplied by 100.

If, for instance, it is necessary to multiply $0.0123 \cdot 24.62 \cdot 1.07461$ and if it is taken that the maximum absolute error in each of these numbers is not over unity in the last figure, then the corresponding relative errors will be:

$$\frac{1}{123}100 = 0.8\%$$

$$\frac{1}{2462}100 = 0.04\%$$

$$\frac{1}{107\,461}100 = 0.001\%$$

The first number has the greatest relative error (0.8%). It follows that the maximum relative error is not less than 0.8 per cent in the product as well. If the first three significant digits 0.325 are kept in the product, the last digit will already be inaccurate, since 0.8 per cent from 0.325 comes to about 0.003.

In cases when rule 1 is observed, i.e., when all numbers used in the calculation contain not more than one inaccurate figure, it is possible to apply the more simple (although less accurate) rule 4,a.

Rule 4,a. *Upon multiplication and division, as a result of calculation, it is necessary to keep a certain number of significant digits which are in the number having these digits least of all among the numbers used in the calculation.*

In the example given above, the first cofactor has three, the second has four, and the third has six significant digits. Consequently, we must leave in the product three significant digits and discard the rest; the result will be 0.325.

Rule 5. *In all the intermediate results, it is necessary to keep one figure more than is required by the preceding rules.* In the final result, this "reserve figure" is discarded.

Rule 6. *If some data have more decimals (upon addition and subtraction) or more significant digits (upon multiplication and division) than others, they must first be rounded, keeping one extra figure* (see rule 5).

Rule 7. *Upon multiplication and division with the aid of logarithms, it is sufficient to have as many figures in the mantissas as there are significant digits in the least accurate multiplier.*

Therefore, for most calculations, we can confine ourselves to the logarithmic table on page 448 of this book.

Together with an excessive as well as an unsubstantiated accuracy of calculations (a long series of figures after the decimal point, when already the first one of them is dubious, the use of multi-place logarithmic tables, and so forth), another error is very common: the unnecessary accuracy of individual measurements that leads to the finding of figures which in any case will be discarded upon subsequent calculations (if these calculations are made correctly).

Analytical chemists, for instance, have grown accustomed to making all weighings on an analytical balance with an accuracy of up to 0.0001 g, and they spent much time sitting by the balance, determining the correct figure in the fourth decimal. At the same time, this accuracy is often pointless. Here are a few examples:

1. Antimony is determined in red copper in which the Sb content is not more than 0.003%. For analysis, a portion of copper weighing 10 g is taken. With what accuracy must the copper shaving be weighed?

The result obtained must have not more than two significant digits, since copper containing even 0.0031% Sb must be discarded. Great accuracy is not needed, and in essence it is unattainable by the analytical methods used. Hence, the maximum absolute error in the final result is ±0.0001%, which makes up ±3.3% of the maximum permissible Sb content in the metal. The calculation is made by the formula

$$x = \frac{a \cdot 100}{g} \%$$

where a = antimony content found;
g = weighed portion.

If a weighed portion of copper is taken with an accuracy of up to one-tenth of a gram (±0.1 g), then with respect to the entire portion weighing 10 g, the relative error will be ±1%, which is far less than ±3.3%. In other words, if instead of 10 g of copper, 9.9 g or 10.1 g are weighed, then with a Sb content of 0.30 mg, this will give, in the first case, 0.00303% and, in the second case, 0.00297%, which in both cases will be rounded off to 0.0030%. It follows that a weighing can be made on technical scales with an accuracy of up to 0.1 g.

2. The accuracy of the colorimetric methods of analysis (if the optical density of solutions is measured visually and not photocolorimetrically or spectrophotometrically) is usually not over ±5% of the relative errors, while by some other methods, the relative error comes to ±10% and more. According to rule 4, the accuracy of the result cannot be higher than the accuracy of the least accurate measurement, and therefore, no matter how accurately a test is weighed for analysis, if this analysis ends with a colorimetric determination, the accuracy of the results will not be higher than the aforementioned ±5%. It follows that if 1 g of a test is weighed with an accuracy of ±0.01 g, i.e., with a maximum relative error of ±1%, this accuracy is high enough.

Visual colorimetric methods are used only to determine the components contained in very small amounts in the substance being analysed, when a great relative error is permissible in the result obtained. The determination of iron in iron ore by the visual colorimetric method leads to impermissible errors.

Note. It must not be assumed that, in determining small amounts, the colorimetric methods of analysis are less accurate than other methods. On the contrary, if in the preceding example Sb is determined not by the colorimetric method (as is usually done), but by the gravimetric method, we would have to weigh about 0.0003 g of Sb_2O_4, which on an ordinary analytical balance can scarcely be made with a maximum error less than ±30% of the relative errors. In addition, no account is taken of the inevitable significant error due to impurities present in the calcined precipitate, an error which cannot be eliminated even when a microbalance is used.

3. In the calculation of the results of volumetric-analytical determinations, the least accurate figure is the number of millilitres of a titrating solution used for titration. Since the hundredth parts of a millilitre are marked approximately, it can be accepted that the maximum measurement error is not less than ±0.02 ml. The error due to the remaining residue is also ±0.02 ml. Therefore, the overall error can be as much as 0.04 ml*. With the total expenditure of 20 ml of the titrating solution, this will come to 0.2% of the relative errors. It follows that, taking 1 g for analysis, the weighing can be performed with an accuracy of up to 1 mg. This gives a relative error of ±0.5 mg, or 0.05%. If less than 20 ml of the titrating solution are used for titration, less accuracy is needed in taking a weighed portion.

On the other hand, the weighing of a starting substance for *establishing the titre* must be performed with an accuracy of up to unity in the fourth decimal, since in this case a portion weighing only about 0.2 g is taken and about 40 ml of the titrating solution are used for titration.

If one wishes to increase the accuracy of the volumetric-analytical methods, one must use gravimetric burettes instead of ordinary ones,** which completely precludes errors due to inaccurate measurement, remaining residue and a difference in temperature. The weighing of a sample now becomes a less accurate operation, and it should be performed with a relative error which is determined by the accuracy required in the final result (±0.01% and less).

The foregoing should not lead to the conclusion that the weighed portion can always be taken with an accuracy of ±1 mg or less. On the contrary, there are some analytical operations when the entire accuracy of an analytical balance must be used, and when even the accuracy of a microbalance is not high enough. Here are two examples.

4. Red electrolytic copper must contain 99.95% of Cu. The analytical determination of Cu in this case is made by electrolysis. What accuracy must the weighing be made with?

The error in the final result, expressed in per cent, must not be more than ±0.004%. It is apparently necessary to have no lesser accuracy in weighing a test of red copper as in weighing a platinum electrode before and after Cu is deposited on it. If one gram of a test is taken for an analysis, then, with the maximum accuracy of the weighing on an analytical balance being ±0.2 mg, the relative error will be ±0.02%, which is far more than is permissible. Therefore, in the given case, it is necessary to use a balance that is more accurate than the ordinary analytical one, or (as is usually done) to take not less than 5 g of the substance being analysed.

5. Suppose that for determining Zn in a copper-zinc alloy containing about 20% of Zn, a portion weighing 0.02 g is taken, whether owing to the small amount of shavings which an analyst has or with due regard to some advantages in the techniques of working with small amounts of a substance. The analysis is concluded by weighing

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* See I. M. Koltgof and E. B. Sendel, *Kolichestvennyi analiz* (*Quantitative Analysis*), Moscow, 1948, p. 459.

** See, for instance, I. M. Koltgof and E. B. Sendel, *Kolichestvennyi analiz* (*Quantitative Analysis*), Moscow, 1948, p. 561; I. M. Koltgof and V. A. Stenger, *Ob'emnyi analiz* (*Volumetric Analysis*), Vol. II, Moscow, 1952, p. 25.

the precipitate in the form of $Zn_2P_2O_7$. What accuracy must the weighing be made with?

The result of the analysis must be expressed with an accuracy of up to a hundredth part of a per cent (for instance, 19.84%), i.e., with a permissible error of ±0.01% of the absolute errors; since the Zn content is 20%, this will come to ±0.05% of the relative errors. The same accuracy must be obtained when weighing the portion of shavings and the calcined precipitate $Zn_2P_2O_7$. When a portion weighs 20 mg, the value ±0.05% comes to ±0.01 mg; the same percentage of the mass of the calcined precipitate (~8 mg) is still less, being about ±0.004 mg. A microchemical balance gives an error of about ±0.01 mg. It follows that, in the given case, the weighing performed even with a microchemical balance does not ensure the required accuracy.

Table 1

Atomic Weights of the Elements

The atomic weights of various elements are determined with different accuracy which is expressed by a different number of figures after the decimal point. When the number expressing atomic weight ends with one or several zeroes, the latter are significant digits showing the accuracy with which the atomic weight of the corresponding element is determined (see rule 1, p. 11).

The results of chemical analyses must not be expressed with a precision greater than that of the atomic weight. This limitation must be especially reckoned with when determining some platinum and rare-earth elements, and also rhenium.

The table contains relative atomic weights published by the Commission on Atomic Weights of the International Union of Pure and Applied Chemistry (IUPAC) in 1965.

The Commission adopted a resolution whereby the old "oxygen chemical unit" of atomic weights (1/16 of the average atomic weight of the natural isotopic mixture of oxygen atoms) is replaced by the "carbon physical unit" (1/12 of the atomic mass of the carbon isotope ^{12}C).

For all the elements, besides those given below, the number expressing the atomic weight is given with an error not exceeding ±0.5 in the last digit after the decimal point. The deviations of the atomic weight values for the given six elements are as follows: boron ±0.003; hydrogen ±0.00001; oxygen ±0.0001; silicon ±0.001; sulphur ±0.003; carbon ±0.00005. These deviations are due to variations in the natural isotopic composition of the elements.

Owing to the experimental inaccuracies in the determination of the atomic weights of the six elements listed below, their values deviate within the following limits: bromine ±0.001; iron ±0.003; copper ±0.001; silver ±0.001; chlorine ±0.001; chromium ±0.001.

The atomic weights of radioactive elements are given only for thorium and uranium; for other radioactive elements, the mass number of the isotope with the longest half-life is given in square brackets.

Element	Symbol	Atomic number	Atomic weight, *a*	log *a*
Actinium	Ac	89	[227]	35 603
Silver	Ag	47	107.868	03 289
Aluminium	Al	13	26.9815	43 106
Americium	Am	95	[243]	38 561
Argon	Ar	18	39.948	60 150
Arsenic	As	33	74.9216	87 461
Astatine	At	85	[210]	32 222
Gold	Au	79	196.967	29 440
Boron	B	5	10.811	03 387
Barium	Ba	56	137.34	13 780

Table 1 (continued)

Element	Symbol	Atomic number	Atomic weight, *a*	log *a*
Beryllium	Be	4	9.0122	95 483
Bismuth	Bi	83	208.980	32 010
Berkelium	Bk	97	[247]	39 620
Bromine	Br	35	79.904	90 257
Carbon	C	6	12.01115	07 958
Calcium	Ca	20	40.08	60 293
Cadmium	Cd	48	112.40	05 077
Cerium	Ce	58	140.12	14 650
Californium	Cf	98	[252]	41 040
Chlorine	Cl	17	35.453	54 965
Curium	Cm	96	[247]	39 270
Cobalt	Co	27	58.9332	77 036
Chromium	Cr	24	51.996	71 597
Caesium	Cs	55	132.905	12 354
Copper	Cu	29	63.546	80 309
Dysprosium	Dy	66	162.50	21 085
Erbium	Er	68	167.26	22 340
Einsteinium	Es	99	[254]	40 483
Europium	Eu	63	151.96	18 173
Fluorine	F	9	18.9984	27 872
Iron	Fe	26	55.847	74 700
Fermium	Fm	100	[257]	40 993
Francium	Fr	87	[223]	34 830
Gallium	Ga	31	69.72	84 336
Gadolinium	Gd	64	157.25	19 659
Germanium	Ge	32	72.59	86 088
Hydrogen	H	1	1.00797	00 345
Helium	He	2	4.0026	60 235
Hafnium	Hf	72	178.49	25 162
Mercury	Hg	80	200.59	30 231
Holmium	Ho	67	164.930	21 730
Iodine	I	53	126.9044	10 348
Indium	In	49	114.82	06 002
Iridium	Ir	77	192.2	28 375
Potassium	K	19	39.102	59 220
Krypton	Kr	36	83.80	92 324
Kurchatovium	Ku	104	[264]	42 160

Table I (continued)

Element	Symbol	Atomic number	Atomic weight, *a*	log *a*
Lanthanum	La	57	138.91	14 273
Lithium	Li	3	6.939	84 130
Lawrencium	Lr	103	[256]	40 824
Lutetium	Lu	71	174.97	24 297
Mendelevium	Md	101	[257]	40 993
Magnesium	Mg	12	24.305	38 570
Manganese	Mn	25	54.9380	73 987
Molybdenum	Mo	42	95.94	98 200
Nitrogen	N	7	14.0067	14 634
Sodium	Na	11	22.9898	36 154
Niobium	Nb	41	92.906	96 804
Neodymium	Nd	60	144.24	15 909
Neon	Ne	10	20.179	30 490
Nickel	Ni	28	58.71	76 871
Nobelium	No	102	[255]	40 654
Neptunium	Np	93	[237]	37 475
Oxygen	O	8	15.9994	20 410
Osmium	Os	76	190.2	27 921
Phosphorus	P	15	30.9738	49 099
Protactinium	Pa	91	[231]	36 361
Lead	Pb	82	207.19	31 637
Palladium	Pd	46	106.4	02 694
Promethium	Pm	61	[145]	16 137
Polonium	Po	84	[210]	32 222
Praseodymium	Pr	59	140.907	14 893
Platinum	Pt	78	195.09	29 024
Plutonium	Pu	94	[244]	38 739
Radium	Ra	88	[226]	35 411
Rubidium	Rb	37	85.47	93 181
Rhenium	Re	75	186.2	26 998
Rhodium	Rh	45	102.905	01 244
Radon	Rn	86	[222]	34 635
Ruthenium	Ru	44	101.07	00 462
Sulphur	S	16	32.064	50 602
Antimony	Sb	51	121.75	08 547
Scandium	Sc	21	44.956	65 279

Table 1 (continued)

Element	Symbol	Atomic number	Atomic weight, a	log a
Selenium	Se	34	78.96	89 741
Silicon	Si	14	28.086	44 849
Samarium	Sm	62	150.35	17 711
Tin	Sn	50	118.69	07 441
Strontium	Sr	38	87.62	94 260
Tantalum	Ta	73	180.948	25 755
Terbium	Tb	65	158.924	20 119
Technetium	Tc	43	[99]	99 564
Tellurium	Te	52	127.60	10 585
Thorium	Th	90	232.038	36 556
Titanium	Ti	22	47.90	68 034
Thallium	Tl	81	204.37	31 042
Thulium	Tm	69	168.934	22 772
Uranium	U	92	238.03	37 663
Vanadium	V	23	50.942	70 708
Tungsten	W	74	183.85	26 446
Xenon	Xe	54	131.30	11 826
Yttrium	Y	39	88.905	94 893
Ytterbium	Yb	70	173.04	23 815
Zinc	Zn	30	65.37	81 538
Zirconium	Zr	40	91.22	96 009

Table 2

Radioactive Elements

Element	Symbol	Atomic number	Mass number of the longest living isotope	Half-life*	Decay mode
Actinium	Ac	89	227	22 y	α, β⁻
Americium	Am	95	243	7.8×10^3 y	α
Astatine	At	85	210	8.3 h	α, Electron capture
Berkelium	Bk	97	247	1.4×10^3 y	α
Californium	Cf	98	252	360 y	α
Curium	Cm	96	247	1.6×10^7 y	α
Einsteinium	Es	99	254	2.7×10^2 d	α
Fermium	Fm	100	257	3 d	Electron capture, α
Francium	Fr	87	223	22 min	α, β⁻
Lawrencium	Lr	103	256	8 s	α
Mendelevium	Md	101	257	1.5 h	Electron capture
Neptunium	Np	93	237	2.1×10^6 y	α
Nobelium	No	102	255	~8 s	α
Plutonium	Pu	94	244	3.8×10^5 y	α
Polonium	Po	84	210	138.4 d	α
Promethium	Pm	61	145	18 y	β⁻
Protactinium	Pa	91	231	3.2×10^4 y	α
Radium	Ra	88	226	1,622 y	α
Radon	Rn	86	222	3.83 d	α
Technetium	Tc	43	99	2.1×10^5 y	β⁻
Thorium	Th	90	232	1.4×10^{10} y	α
Uranium	U	92	238	4.5×10^9 y	α

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* s, second; min, minute; h, hour; d, day; y, year.

Table 3

Ion Radii

The values of ion radii are given in angstroms (Å) with a coordination number of 6. When the coordination number is 4, the correction comes to —6%, with the coordination number of 8, it is +3%, and with the coordination number of 12, it comes to +12%.

Substance	Ionic charge	Size of radius, Å, according to			
		Goldschmidt	Pauling	Belov and Boky	other sources
Ac	+3	—	—	1.11	1.19
Ag	+1	1.13	1.26	1.13	—
Al	+3	0.57	0.50	0.57	—
Am	+4	—	—	0.85	—
	+3	—	—	1.00	0.99
As	+5	—	0.47	0.47	—
	+3	0.69	—	0.69	0.58
	—3	—	2.22	1.91	—
	+4	—	—	—	0.89
Au	+3	—	—	0.85	0.90
	+1	—	1.37	1.37	—
B	+3	—	0.20	0.21	—
BF_4^-	—1	—	—	—	2.28
Ba	+2	1.43	1.35	1.38	—
Be	+2	0.34	0.31	0.34	—
Bi	+5	—	0.74	0.74	—
	+3	—	—	1.20	1.16
	—3	—	—	2.13	—
Br	+7	—	0.39	0.39	—
	+5	—	—	—	0.47
	—1	1.96	1.95	1.96	—
C	+4	0.2	0.15	0.20	—
	—4	—	2.60	2.60	—
CN^-	—1	—	—	—	1.92
Ca	+2	1.06	0.99	1.04	—
Cd	+2	1.03	0.97	0.99	0.92
Ce	+4	1.02	1.01	0.88	0.93; 0.87
	+3	1.18	—	1.02	1.00; 1.02
Cl	+7	—	0.26	0.26	—
	+5	—	—	—	0.34
	—1	1.81	1.81	1.81	—
ClO_4^-	—1	—	—	—	2.36
Co	+3	0.64	—	0.64	0.72
	+2	0.82	0.72	0.78	0.78; 0.80
Cr	+6	0.35	—	0.35	—

Table 3 (continued)

Substance	Ionic charge	Size of radius, Å, according to			
		Goldschmidt	Pauling	Belov and Boky	other sources
	+3	—	—	0.64	0.62
	+2	0.83	—	0.83	—
CrO_4^{2-}	−2	—	—	—	3.00
Cs	+1	1.65	1.69	1.65	—
Cu	+2	0.70	—	0.80	0.69; 0.82
	+1	—	0.96	0.98	0.95
Dy	+3	1.07	—	0.88	0.91
Er	+3	1.04	—	0.85	0.87
Eu	+3	1.13	—	0.97	0.96
	+2	—	—	—	1.09; 1.24
F	+7	—	0.07	0.07	—
	−1	1.33	1.36	1.33	—
Fe	+3	0.67	—	0.67	0.73
	+2	0.83	0.75	0.80	0.75
Ga	+3	0.62	0.62	0.62	—
Gd	+3	1.11	—	0.94	0.94
Ge	+4	0.44	0.53	0.44	—
	+2	—	—	0.65	0.98; 0.73
	−4	—	2.72	—	—
H	−1	1.54	2.08	1.36	—
Hf	+4	—	—	0.82	0.86
Hg	+2	1.12	1.10	1.12	1.05
Ho	+3	1.05	—	0.86	0.89
I	+7	—	0.50	0.50	—
	+5	0.94	—	—	0.98
	+1	—	—	—	1.30
	−1	2.20	2.16	2.20	2.19
In	+3	0.92	0.81	0.92	—
	+1	—	—	1.30	—
Ir	+4	0.66	0.64	0.65	0.75; 0.68
	+3	—	—	—	0.81
	+2	—	—	—	0.89
K	+1	1.33	1.33	1.33	—
La	+4	—	—	0.90	—
	+3	1.22	1.15	1.04	—
Li	+1	0.78	0.60	0.68	—
Lu	+3	0.99	—	0.80	0.84
Mg	+2	0.78	0.65	0.74	—
Mn	+7	—	0.46	0.46	—
	+4	0.52	0.50	0.52	—
	+3	0.70	—	0.70	0.67
	+2	0.91	0.80	0.91	—
Mo	+6	—	0.62	0.65	—
	+4	0.68	0.66	0.68	—

Table 3 (continued)

Substance	Ionic charge	Size of radius, Å, according to			
		Goldschmidt	Pauling	Belov and Boky	other sources
MoO_4^{2-}	−2	—	—	—	3.45
N	+5	0.15	0.11	0.15	0.13
	+3	—	—	—	0.16
	−3	—	1.71	1.48	1.30
NH_4^+	+1	1.43	—	—	1.59
NO_3^-	−1	—	—	—	1.89; 2.57
Na	+1	0.98	0.95	0.98	—
Nb	+5	0.69	0.70	0.66	—
	+4	0.69	0.67	0.67	0.74
Nd	+3	1.15	—	0.99	0.99
Ni	+3	0.35	—	—	—
	+2	0.78	0.69	0.74	0.68; 0.79
Np	+6	—	—	—	0.82
	+5	—	—	—	0.88
	+4	—	—	0.88	0.92
	+3	—	—	1.02	1.01
O	+6	—	0.09	0.09	—
	−2	1.32	1.40	1.36	1.45
OH^-	−1	—	—	—	1.53; 1.33
OH_3^+	+1	—	—	—	1.35
Os	+4	0.67	0.65	0.65	0.75
	+3	—	—	—	0.81
	+2	—	—	—	0.89
P	+5	0.35	0.34	0.35	—
	+3	—	—	—	0.44
	−3	—	2.12	1.86	—
PO_4^{3-}	−3	—	—	—	3.00
Pa	+4	—	—	0.91	0.96
	+3	—	—	1.06	1.05
Pb	+4	0.84	0.84	0.76	—
	+2	1.32	1.21	1.26	1.17
Pd	+4	—	—	0.64	0.73; 0.65
	+2	—	—	—	0.72; 0.88
Pm	+3	—	—	0.98	0.98
Pr	+4	1.00	0.92	—	0.92
	+3	1.16	—	1.00	1.00
Pt	+4	—	—	0.64	0.76
	+2	—	—	—	0.90; 0.87
	+6	—	—	—	0.81
	+5	—	—	—	0.87
Pu	+4	—	—	0.86	0.90
	+3	—	—	1.02	1.00
Ra	+2	1.52	—	1.44	—
Rb	+1	1.49	1.48	1.49	—

Table 3 (continued)

Substance	Ionic charge	Size of radius, Å, according to			
		Goldschmidt	Pauling	Belov and Boky	other sources
Re	+7	—	—	—	0.56
	+6	—	—	0.52	0.55
	+4	—	—	0.72	0.71
Rh	+4	—	—	0.65	0.62
	+3	—	—	0.75	0.62
Ru	+4	0.65	0.63	0.62	0.71
	+3	—	—	—	0.74
	+2	—	—	—	0.85
S	+6	0.34	0.29	0.30	—
	+4	—	—	—	0.37
	−2	1.74	1.84	1.86	1.90
SH^-	−1	—	—	—	2.00
SO_4^{2-}	−2	—	—	—	2.95
HSO_4^-	−1	—	—	—	2.06
Sb	+5	—	0.62	0.62	—
	+3	0.90	—	0.90	—
	−3	—	2.45	2.08	—
Sc	+3	0.83	0.81	0.83	—
Se	+6	—	—	0.35	0.42
	+4	—	—	0.69	0.56
	−2	1.91	1.98	1.93	1.91
Si	+4	0.39	0.41	0.39	—
	−4	—	2.71	—	—
SiO_4^{4-}	−4	—	—	—	2.90
Sm	+3	1.13	—	0.97	0.97
	+2	—	—	—	1.11
Sn	+4	0.74	0.71	0.67	—
	+2	—	—	1.02	—
	−4	—	2.94	—	—
Sr	+2	1.27	1.13	1.20	1.10
Ta	+5	—	—	0.66	0.73
Tb	+3	1.09	—	0.89	0.92
Te	+6	—	0.56	0.56	0.61
	+4	0.89	0.81	0.89	—
	−2	2.11	2.21	2.22	—
Th	+4	1.10	1.02	0.95	0.99
	+3	—	—	1.08	1.08
Ti	+4	0.64	0.68	0.64	—
	+3	0.69	—	0.69	—
	+2	0.80	—	0.78	0.76
Tl	+3	1.05	0.95	1.05	—
	+1	1.49	1.44	1.36	—
Tm	+3	1.04	—	0.85	0.86

Table 3 (continued)

Substance	Ionic charge	Size of radius, Å, according to			
		Goldschmidt	Pauling	Belov and Boky	other sources
U	+6	—	—	—	0.83
	+5	—	—	—	0.87
	+4	1.05	0.97	0.95	0.93; 0.89
	+3	—	—	1.04	1.03
V	+5	0.4	0.59	—	0.59
	+4	0.61	0.59	0.61	0.64
	+3	0.65	—	0.67	—
	+2	0.72	—	0.72	—
W	+6	—	—	0.65	—
	+4	0.68	0.66	0.68	—
Y	+3	1.06	0.93	0.97	—
Yb	+3	1.00	—	0.81	0.85
Zn	+2	0.83	0.74	0.83	0.70
Zr	+4	0.87	0.80	0.82	—

Table 4

Ionization Potentials of Atoms and Ions

The ionization potential is the minimum voltage of the electric field needed for tearing away one electron from an atom or ion.

The table gives the potentials of the ionization of atoms and ions, i.e., the potentials required for separating one electron from a neutral unexcited atom ($X - e \rightarrow X^+$) and the potentials required for tearing away one electron from a single-charge (positive) unexcited ion ($X^+ - e \rightarrow X^{2+}$), from a two-charge unexcited ion ($X^{2+} - e \rightarrow X^{3+}$) and so forth.

Insufficiently reliable data are given in parentheses.

Element	$X - e \rightarrow X^+$	$X^+ - e \rightarrow X^{2+}$	$X^{2+} - e \rightarrow X^{3+}$	$X^{3+} - e \rightarrow X^{4+}$	$X^{4+} - e \rightarrow X^{5+}$	$X^{5+} - e \rightarrow X^{6+}$
Ac	6.89	11.5	—	—	—	—
Ag	7.57	21.48	6.10	(52)	(70)	(89)
Al	5.98	18.82	28.44	119.96	153.8	190.4
Ar	15.76	27.62	40.90	59.79	75.0	91.3
As	9.81	18.7	28.3	50.1	62.9	127.5
Au	9.22	20.5	30.5	(44)	(58)	(73)
B	8.30	25.15	37.92	259.30	340.13	—
Ba	5.81	10.00	37	(49)	(62)	(80)
Be	9.32	18.21	153.9	217.7	—	—
Bi	7.29	19.3	25.6	45.3	56.0	94.4
Br	11.84	21.6	35.9	47.3	59.7	88.6
C	11.26	24.38	47.86	64.48	392.0	489.8
Ca	6.11	11.87	51.21	67.3	84	109
Cd	8.99	16.90	44.5	(55)	(73)	(94)
Ce	6.91	12.3	19.5	36.7	(70)	(85)
Cl	13.01	23.80	39.9	53.3	67.8	96.6
Co	7.86	17.05	33.5	(53)	(82)	(109)
Cr	6.76	16.49	31	(51)	73	90.6
Cs	3.89	25.1	34.6	(46)	(62)	(74)
Cu	7.72	20.29	36.83	(59)	(83)	(109)
Dy	6.82	—	—	—	—	—
Eu	5.67	11.24	—	—	—	—
F	17.42	34.98	62.65	87.23	114.2	157.1
Fe	7.90	16.18	30.64	(56)	(79)	103
Ga	6.00	20.51	30.70	64.2	(90)	(118)
Gd	6.16	12	—	—	—	—
Ge	7.88	15.93	34.21	45.7	93.4	(123)
H	13.60	—	—	—	—	—
He	24.58	54.40	—	—	—	—

Table 4 (continued)

Element	$X - e \rightarrow X^+$	$X^+ - e \rightarrow X^{2+}$	$X^{2+} - e \rightarrow X^{3+}$	$X^{3+} - e \rightarrow X^{4+}$	$X^{4+} - e \rightarrow X^{5+}$	$X^{5+} - e \rightarrow X^{6+}$
Hf	5.5	14.9	(21)	(31)		—
Hg	10.43	18.75	34.2	(46)	(61)	(77)
I	10.44	19.0	33	(42)	71	83
In	5.79	18.86	28.0	58	(77)	(98)
K	4.34	31.8	45.9	61.1	82.6	99.4
Kr	14.00	24.56	36.9	52.5	64.7	78.5
La	5.61	11.43	19.17	(52)	(66)	(80)
Li	5.39	75.62	122.4	—	—	—
Lu	6.15	14.7	(19)	—	—	—
Mg	7.64	15.03	78.2	109.3	141.2	186.8
Mn	7.43	15.64	33.69	(53)	(76)	100
Mo	7.13	15.72	29.6	46.4	61.2	67
N	14.54	29.60	47.43	77.45	97.86	552
Na	5.14	47.29	71.65	98.88	138.6	172.4
Nb	6.88	13.90	28.1	38.3	50	110.4
Nd	6.31	—	—	—	—	—
Ne	21.56	41.07	63.5	97.2	126.4	157.9
Ni	7.63	18.15	36.16	56	79	113
O	13.61	35.15	54.93	77.39	113.9	138.1
Os	8.7	17	25	40	54	68
P	10.55	19.65	30.16	51.35	65.01	220.4
Pb	7.42	15.03	31.93	39.0	69.7	84
Pd	8.33	19.42	(33)	(49)	(66)	(90)
Po	8.2	19.4	27.3	(38)	(61)	(73)
Pr	5.76	—	—	—	—	—
Pt	8.96	18.54	(29)	(41)	(55)	(75)
Ra	5.28	10.14	(34)	(46)	(59)	(76)
Rb	4.18	27.56	40	52.6	71.0	84.4
Re	7.87	16.6	(26)	(38)	(51)	(65)
Rh	7.46	15.92	32.8	(46)	(67)	(85)
Rn	10.75	21.4	29.4	(44)	(55)	(67)
Ru	7.36	16.60	30.3	(47)	(63)	(81)
S	10.36	23.4	34.8	47.3	72.5	88.0
Sb	8.64	16.7	24.8	44.1	63.8	119
Sc	6.56	12.89	24.75	73.9	91.8	111
Se	9.75	21.5	32.0	42.9	68.3	82.1
Si	8.15	16.34	33.46	45.1	166.7	205.1
Sm	5.6	11.2	—	—	—	—
Sn	7.33	14.6	30.7	46.4	91	(103)
Sr	5.69	11.03	43.6	57.1	71.6	90.8
Ta	7.7	16.2	(22)	(33)	(45)	-
Tb	6.74	—		—	—	—

Table 4 (continued)

Element	$X - e \to X^{+}$	$X^{+} - e \to X^{2+}$	$X^{2+} - e \to X^{3+}$	$X^{3+} - e \to X^{4+}$	$X^{4+} - e \to X^{5+}$	$X^{5+} - e \to X^{6+}$
Tc	7.23	14.87	31.9	(43)	(59)	(76)
Te	9.01	18.8	31	38	66	83
Th	—	11.5	20.0	28.7	(65)	(80)
Ti	6.83	13.57	28.14	43.24	99.8	119
Tl	6.11	20.42	29.8	50	(64)	(81)
V	6.74	14.2	29.7	48.0	65.2	128.9
W	7.98	17.7	(24)	(35)	(48)	(61)
Xe	12.13	21.2	32.1	(45)	(57)	89
Y	6.38	12.23	20.5	61.8	77.0	93.0
Yb	6.2	12.10	—	—	—	—
Zn	9.39	17.96	39.70	(62)	(86)	(114)
Zr	6.84	12.92	24.8	33.97	82.3	99.4

Table 5

Structures of Outer Electron Layers, Ion Potentials and Analytical Groups of Cations (according to N. I. Blok)

(Under the cation symbols, we give the values of ionic potentials Z/R: the ratio of the charge of an ion to its radius)

Complete 2- or 8-electron external layer

Cs^+	Rb^+	NH_4^+	K^+	Na^+	Li^+	Ra^{2+}	Ba^{2+}	Sr^{2+}	Ca^{2+}	La^{3+}	Ce^{3+}	Mg^{2+}	Y^{3+}	Sc^{3+}	Zr^{4+}	Hf^{4+}	Al^{3+}	Be^{2+}	Ti^{4+}
0.6	0.7	0.7	0.8	1.0	1.3	1.3	1.4	1.6	1.9	2.5	2.5	2.6	2.8	3.6	4.6	4.6	5.3	5.9	6.2
I group						II group				1st subgroup of III group									

Incomplete 18-electron external layer

Mn^{2+}	Fe^{2+}	Co^{2+}	Ni^{2+}	Fe^{3+}	Cr^3	Cu^{2+}	Ru^{3+}	Rh^{3+}	Os^{IV}	Ir^{IV}
2.2	2.4	2.4	2.6	4.5	4.6	2.5	?	4.4	6.0	6.0
2nd subgroup of III group						IV and V groups				

Complete 18-electron external layer

Au^+	Ag^+	Cu^+	Hg^{2+}	Cd^{2+}	Zn^{2+}	In^{3+}	Ga^{3+}	Sn^{IV}	Ge^{IV}	Sb^V	As^V
0.7	0.9	1.0	1.8	1.9	2.4	3.3	4.9	5.4	7.5	8.1	10.6
IV group							V group				

External electron structure 18+2

Tl^+	Pb^{2+}	Sn^{2+}	Bi^{3+}	Sb^{III}	As^{III}
0.6	1.5	1.9	2.6	3.3	4.4
IV group				V group	

Table 6

Atomic Weights, Molecular Weights*, Weights of Atomic Groups, and Their Logarithms

In compiling this table, all additions of atomic weights have been made in conformity with rules 2 and 3 (p. 11), the needless decimals having been discarded.

The atomic weights of all elements (apart from the 12 elements given below) are expressed in numbers in which errors are within the limits of ±0.5 in the last figure.

When a fractional part of an atomic weight is being found, the error in its magnitude apparently passes over to the next decimal, which now becomes the first of dubious figures. The total number of figures after the decimal point thus increases by unity. If, for instance, the atomic weight of titanium (Ti) is 47.90, then one-half of this atomic weight (1/2 Ti) will be not 23.95, but 23.950; Sn = 118.69, 1/2 Sn = 59.345.

When a multiple of an atomic weight is being found, the error increases. If, for instance, it is necessary to increase the atomic weight 10 times, its value must be rounded off by reducing the number of figures after the decimal point by one figure. For example, the atomic weight of nitrogen (N) is 14.0067; while 10 N is not 140.067, but 140.07.

The multiplication of the atomic weight of iron only by 2 gives an error within the limits of ±0.006 and, consequently, an error can be made in the preceding figure; therefore, if Fe = 55.847, then 2 Fe will be not 111.694, but 111.69. When dividing the atomic weight of iron by 3, we have the maximum error within the limits of ±0.0001 and, consequently, the number of figures after the decimal point will not increase: 1/3 Fe = 18.615.

One must be guided by such considerations also when adding the atomic weights of various elements: if the sum of the maximum possible errors is either equal to or more than ±5 in the last figure, a rounding must be made by reducing the number of figures after the decimal point by unity.

Formula	Weight, *a*	log *a*
Ag	107.868	03 289
2Ag	215.736	33 392
3Ag	323.604	51 001
Ag_3AsO_3	446.524	64 984
Ag_3AsO_4	462.523	66 513
AgBr	187.772	27 363

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* The molecular weights of solvents and organic reagents not included in this table are given in tables 44 and 49, respectively.

Table 6 (continued)

Formula	Weight, *a*	log *a*
$AgC_2H_3O_2$ (acetate)	166.913	22 249
$AgC_7H_4NS_2$ (mercaptobenzothiazolide)	274.11	43 792
$AgCN$	133.886	12 674
Ag_2CO_3	275.741	44 050
$AgCl$	143.321	15 631
Ag_2CrO_4	331.730	52 078
$Ag_2Cr_2O_7$	431.730	63 521
AgF	126.866	10 335
$Ag_3Fe(CN)_6$	535.56	72 881
$Ag_4Fe(CN)_6$	643.43	80 850
AgI	234.772	37 065
$AgNO_2$	153.874	18 717
$AgNO_3$	169.873	23 012
Ag_2O	231.735	36 499
$AgOCN$	149.885	17 576
Ag_3PO_4	418.575	62 177
Ag_2S	247.80	39 410
$AgSCN$	165.950	21 998
Ag_2SO_4	311.80	49 388
$AgVO_3$	206.808	31 555
Ag_3VO_4	438.544	64 201
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Al	26.9815	43 106
$^1/_3Al$	8.99383	95 394
$2Al$	53.9630	73 210
$3Al$	80.9445	90 819
$4Al$	107.9260	03 313
$5Al$	134.9075	13 003
$6Al$	161.8890	20 922
$AlBr_3$	266.694	42 601
$Al(C_2H_3O_2)_3$ (acetate)	204.117	30 988
$Al(C_9H_6ON)_3$ (hydroxyquinolate)	459.444	66 223
$AlCl_3$	133.341	12 496
$AlCl_3 \cdot 6H_2O$	241.433	38 280
AlF_3	83.9767	92 416
AlF_6	140.9719	14 913
$AlK(SO_4)_2 \cdot 12H_2O$	*See* $KAl(SO_4)_2 \cdot 12H_2O$	
$AlNH_4(SO_4)_2 \cdot 12H_2O$	*See* $NH_4Al(SO_4)_2 \cdot 12H_2O$	
$Al(NO_3)_3$	212.996	32 837
$Al(NO_3)_3 \cdot 9H_2O$	375.134	57 419
Al_2O_3	101.9612	00 843

Table 6 (continued)

Formula	Weight, *a*	log *a*
$^1/_6Al_2O_3$	16.9935	23 028
$Al(OH)_3$	78.0036	89 211
$AlPO_4$	121.953	08 619
$Al_2(SO_4)_3$	342.15	53 422
$Al_2(SO_4)_3 \cdot 18H_2O$	666.42	82 375
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
As	74.9216	87 461
$^1/_2As$	37.46080	57 358
$^1/_3As$	24.97387	39 748
$^1/_5As$	14.98432	17 564
2As	149.8432	17 564
$AsBr_3$	314.634	49 781
$AsCl_3$	181.281	25 835
$AsCl_5$	252.187	40 172
AsH_3	77.9455	89 179
AsO_3	122.9198	08 962
AsO_4	138.9192	14 276
As_2O_3	197.8414	29 632
$^1/_4As_2O_3$	49.4603	69 426
As_2O_5	229.8402	36 143
As_2O_7	261.8390	41 803
AsS_4	203.18	30 788
As_2S_3	246.04	39 101
As_2S_5	310.16	49 159
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Au	196.967	29 439
$^1/_3Au$	65.6557	81 727
2Au	393.934	59 542
AuCN	222.985	34 828
$Au(CN)_2$	249.003	39 620
$Au(CN)_4$	301.038	47 862
$AuCl_3$	303.326	48 191
$AuCl_3 \cdot 2H_2O$	339.357	53 066
$AuCl_4$	338.779	52 992
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
B	10.811	03 387
$^1/_3B$	3.604	55 678
2B	21.62	33 490
3B	32.43	51 099
4B	43.24	63 593

Table 6 (continued)

Formula	Weight, a	log a
BBr_3	250.52	39 884
BCl_3	117.17	06 882
BF_3	67.806	83 127
BF_4	86.805	93 854
BO_2	42.810	63 155
BO_3	58.809	76 944
B_2O_3	69.62	84 273
B_4O_7	155.24	19 100
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ba	137.34	13 780
$^1/_2Ba$	68.670	83 677
2Ba	274.68	43 883
3Ba	412.02	61 492
$BaBr_2$	297.15	47 298
$BaBr_2 \cdot 2H_2O$	333.18	52 268
$BaCO_3$	197.35	29 524
$Ba(C_2H_3O_2) \cdot H_2O$ (acetate)	273.45	43 688
BaC_2O_4 (oxalate)	225.36	35 288
$BaCl_2$	208.25	31 859
$BaCl_2 \cdot 2H_2O$	244.28	38 789
$Ba(ClO_3)_2 \cdot H_2O$	322.26	50 821
$BaClO_4$	236.79	37 436
$BaClO_4 \cdot 3H_2O$	290.84	46 365
$BaCrO_4$	253.33	40 369
BaF_2	175.34	24 388
$Ba(NO_3)_2$	261.35	41 722
BaO	153.34	18 566
$^1/_2BaO$	76.67	88 463
BaO_2	169.34	22 876
$Ba(OH)_2$	171.35	23 388
$Ba(OH)_2 \cdot 8H_2O$	315.48	49 899
$^1/_2Ba(OH)_2 \cdot 8H_2O$	157.74	19 794
$BaSO_3$	217.40	35 679
$BaSO_4$	233.40	36 810
$BaSeO_4$	280.30	44 762
$BaSiF_6$	279.42	44 626
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Be	9.0122	95 483
$^1/_2Be$	4.50610	65 380
2Be	18.0244	25 586

Table 6 (continued)

Formula	Weight, *a*	log *a*
$BeCO_3$	69.0216	83 898
$BeCO_3 \cdot 4H_2O$	141.0829	14 947
$BeCl_2$	79.918	90 264
$BeCl_2 \cdot 4H_2O$	151.980	18 179
BeF_2	47.0090	67 218
BeF_4	85.0058	92 945
$Be(NO_3)_2 \cdot 3H_2O$	187.068	27 200
BeO	25.0116	39 814
$Be(OH)_2$	43.0269	63 374
$Be_2P_2O_7$	191.968	28 323
$BeSO_4$	105.074	02 149
$BeSO_4 \cdot 4H_2O$	177.135	24 830
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Bi	208.980	32 010
$^1/_3Bi$	69.6600	84 298
$2Bi$	417.960	62 113
$BiC_6H_3O_3$ (pyrogallate)	332.069	52 123
$Bi(C_9H_6ON)_3$ (hydroxyquinolate)	641.443	80 716
$Bi(C_9H_6ON)_3 \cdot H_2O$ (hydroxyquinolate)	659.458	81 919
$Bi(C_{12}H_{10}ONS)_3 \cdot H_2O$ (thionalide)	875.85	94 243
$BiCl_3$	315.339	49 878
$BiCr(SCN)_6$	609.47	78 495
BiI_3	589.693	77 063
BiI_4	716.598	85 528
$(BiI_4H)(C_9H_7ON)$ (hydroxyquinoline)	862.768	93 589
$(BiI_4H)(C_{10}H_9N)$ (quinaldine)	860.796	93 490
$Bi(NO_3)_3$	394.995	59 659
$Bi(NO_3)_3 \cdot 5H_2O$	485.071	68 580
Bi_2O_3	465.958	66 834
$(BiO)_2CO_3 \cdot {}^1/_2H_2O$	518.976	71 515
$BiOBr$	304.883	48 413
$BiOCl$	260.432	41 569
$(BiO)_2Cr_2O_7$	665.947	82 344
$BiONO_3 \cdot H_2O$	305.000	48 430
$BiPO_4$	303.951	48 280
Bi_2S_3	514.15	71 109
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, *a*	log *a*
Br	79.904	90 257
2Br	159.808	20 360
3Br	239.712	37 969
4Br	319.616	50 463
5Br	399.52	60 154
6Br	479.42	68 072
BrO	95.903	98 183
BrO_3	127.902	10 688
$^1/_6BrO_3$	21.3170	32 873
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
C	12.01115	07 958
2C	24.0223	38 061
3C	36.0335	55 671
4C	48.0446	68 164
5C	60.0558	77 855
6C	72.0669	85 774
7C	84.0781	92 468
8C	96.0892	98 267
CCl_4	153.823	18 702
CH_2	14.0271	14 697
$2CH_2$	28.0542	44 800
$3CH_2$	42.0813	62 409
$4CH_2$	56.1084	74 903
$5CH_2$	70.1355	84 594
$6CH_2$	84.1625	92 512
CH_3	15.0351	17 711
$2CH_3$	30.0701	47 814
$3CH_3$	45.1052	65 423
$4CH_3$	60.1402	77 916
$5CH_3$	75.1753	87 608
$6CH_3$	90.2104	95 526
CH_4	16.0430	20 529
C_2H_2	26.0382	41 561
C_2H_5	29.0622	46 333
$2C_2H_5$	58.1243	76 436
$3C_2H_5$	87.1865	94 045
C_6H_5	77.1068	88 709
$2C_6H_5$	154.2135	18 812
$3C_6H_5$	231.3203	36 421
$C_{10}H_6$	126.1593	10 092
$C_{10}H_7$	127.1673	10 437
$C_{10}H_8$ (naphthalene)	128.1753	10 780
CH_3Br	94.939	97 744

Table 6 (continued)

Formula	Weight, *a*	log *a*
$CHCl_3$	119.378	07 892
CH_3Cl	50.488	70 319
CH_3F	34.0335	53 191
CH_3I	141.9395	15 210
CH_2N_2	42.0405	62 367
$2CH_2N_2$	84.0810	92 470
$C_2H_8N_2$ (ethylenediamine)	60.0995	77 887
C_5H_5N (pyridine)	79.1023	89 819
$2C_5H_5N$	158.2046	19 922
$C_{20}H_{16}N_4$ (nitron)	312.3773	49 468
$C_{20}H_{16}N_4 \cdot HClO_4$	412.836	61 578
$C_{20}H_{16}N_4 \cdot HNO_3$	375.3902	57 448
CH_2O	30.0265	47 750
CH_3O	31.0345	49 184
$2CH_3O$	62.0689	79 287
CH_4O	32.0424	50 573
C_2H_3O	43.0456	63 393
C_2H_6O	46.0695	66 341
$C_4H_4O_6$ (tartrate-ion)	148.0729	17 048
C_6H_6O (phenol)	94.1141	97 365
$C_7H_6O_2N$ (anthranilate-ion)	136.1314	13 396
C_9H_6ON (hydroxyquinolate-ion)	144.1543	15 883
C_9H_7ON (hydroxyquinoline)	145.1622	16 185
CN	26.0179	41 527
$2CN$	52.0357	71 630
$3CN$	78.0536	89 239
$4CN$	104.0714	01 733
$5CN$	130.0893	11 424
$6CN$	156.1071	19 342
CNO *see* OCN		
CNS *see* SCN		
CO	28.0106	44 732
$CO(NH_2)_2$	60.0558	77 855
CO_2	44.0100	64 355
$\frac{1}{2}CO_2$	22.0050	34 252
$2CO_2$	88.0199	94 458
$3CO_2$	132.0299	12 067
CO_3	60.0094	77 822
$\frac{1}{2}CO_3$	30.0047	47 719

Table 6 (continued)

Formula	Weight, *a*	log *a*
$2CO_3$	120.0187	07 986
$3CO_3$	180.0281	25 534
C_2O_4	88.0199	94 458
CO_2H	45.0179	65 339
CS_2	76.139	88 161
$CS(NH_2)_2$	76.120	88 150
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ca	40.08	60 293
$^1/_2Ca$	20.040	30 190
2Ca	80.16	90 396
3Ca	120.24	08 005
$CaBr_2$	199.89	30 079
$CaBr_2 \cdot 6H_2O$	307.98	48 852
CaC_2	64.10	80 686
$Ca(CHO_2)_2$ (formate)	130.12	11 434
$Ca(C_2H_3O_2)_2$ (acetate)	158.17	19 912
$Ca(C_3H_5O_3)_2$ (lactate)	218.22	33 889
$Ca(C_3H_5O_3)_2 \cdot 5H_2O$	308.30	48 897
$Ca_3(C_6H_5O_7)_2$ (citrate)	498.45	69 762
$Ca_3(C_6H_5O_7)_2 \cdot 4H_2O$	570.51	75 626
$Ca(C_{10}H_7N_4O_5)_2 \cdot 8H_2O$ (picrolonate)	710.58	85 161
$CaCN_2$ (cyanamide)	80.10	90 363
$CaCO_3$	100.09	00 039
$^1/_2CaCO_3$	50.045	69 936
CaC_2O_4	128.10	10 755
$^1/_2CaC_2O_4$	64.050	80 652
$CaC_2O_4 \cdot H_2O$	146.12	16 471
$CaCl_2$	110.99	04 528
$CaCl_2 \cdot 6H_2O$	219.08	34 060
$Ca(ClO)_2$	142.98	15 528
$Ca(ClO)_2 \cdot 4H_2O$	215.05	33 254
$CaCrO_4$	156.07	19 332
$CaCrO_4 \cdot 2H_2O$	192.10	28 353
CaF_2	78.08	89 254
$Ca_2Fe(CN)_6 \cdot 12H_2O$	508.30	70 612
CaH_2	42.10	62 428
$Ca(HCO_3)_2$	162.11	20 981
$^1/_2Ca(HCO_3)_2$	81.057	90 879
$CaHPO_4$	136.06	13 373

Table 6 (continued)

Formula	Weight, *a*	log *a*
$CaHPO_4 \cdot 2H_2O$	172.09	23 576
$Ca(H_2PO_4)_2$	234.05	36 931
$Ca(H_2PO_4)_2 \cdot H_2O$	252.07	40 152
$Ca(HS)_2 \cdot 6H_2O$	214.32	33 106
$Ca(HSO_3)_2$	202.22	30 582
CaI_2	293.89	46 818
$CaMoO_4$	200.02	30 107
$Ca(NO_3)_2$	164.09	21 508
$Ca(NO_3)_2 \cdot 4H_2O$	236.15	37 319
CaO	56.08	74 881
$^1/_2CaO$	28.040	44 778
$2CaO$	112.16	04 984
$Ca(OH)_2$	74.09	86 976
$^1/_2Ca(OH)_2$	37.047	56 875
$Ca(PO_3)_2$	198.02	29 671
$Ca_3(PO_4)_2$	310.18	49 161
CaS	72.14	85 818
$CaSO_3$	120.14	07 969
$CaSO_3 \cdot 2H_2O$	156.17	19 360
$CaSO_4$	136.14	13 399
$CaSO_4 \cdot {}^1/_2H_2O$	145.15	16 182
$CaSO_4 \cdot 2H_2O$	172.17	23 596
CaS_2O_3	152.21	18 244
$CaS_2O_3 \cdot 6H_2O$	260.30	41 547
$CaSiF_6$	182.16	26 045
$CaSiO_3$	116.16	06 506
$CaWO_4$	287.93	45 929
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Cd	112.40	05 077
$^1/_2Cd$	56.200	74 974
$2Cd$	224.80	35 180
$CdBr_2$	272.21	43 490
$CdBr_2 \cdot 4H_2O$	344.27	53 690
$Cd(C_2H_3O_2)_2$ (acetate)	230.49	36 265
$Cd(C_2H_3O_2)_2 \cdot 2H_2O$	266.52	42 573
$Cd(C_5H_5N)_2(SCN)_2$ (pyridine)	386.77	58 745
$Cd(C_5H_5N)_4(SCN)_2$	544.97	73 637
$Cd(C_7H_4NS_2)_2$ (mercaptobenzothiazolide)	444.89	64 825
$Cd(C_7H_6O_2N)_2$ (anthranilate)	384.66	58 508
$Cd(C_9H_6ON)_2$ (hydroxyquinolate)	400.71	60 283

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Cd(C_9H_6ON)_2\cdot 2H_2O$	436.74	64 022
$Cd(C_{10}H_6O_2N)_2$ (quinaldinate)	456.73	65 966
$Cd(CN)_2$	164.44	21 601
$CdCO_3$	172.41	23 656
$CdCl_2$	183.31	26 319
$CdCl_2\cdot H_2O$	201.32	30 389
$CdCl_2\cdot 2.5H_2O$	228.34	35 858
$CdHg(SCN)_4$	545.32	73 665
CdI_2	366.21	56 373
$CdNH_4PO_4\cdot H_2O$	243.43	38 637
$Cd(NO_3)_2$	236.40	37 365
$Cd(NO_3)_2\cdot 4H_2O$	308.47	48 921
CdO	128.40	10 857
$Cd(OH)_2$	146.41	16 557
$Cd_2P_2O_7$	398.74	60 069
CdS	144.46	15 975
$CdSO_4$	208.46	31 902
$CdSO_4\cdot {}^8/_3H_2O$	256.50	40 909
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ce	140.12	14 650
$^1/_4Ce$	35.030	54 444
$^1/_3Ce$	46.707	66 938
2Ce	280.24	44 753
$Ce(C_2H_{10}N_2)_2(SO_4)_4\cdot 7H_2O$ (ethylene diammonium)	774.70	88 913
$Ce(C_9H_6ON)_3$ (hydroxyquinolate)	572.58	75 784
$Ce_2(C_2O_4)_3$	544.30	73 584
$Ce_2(C_2O_4)_3\cdot 9H_2O$	706.44	84 908
$CeCl_3$	246.48	39 178
$CeCl_3\cdot 7H_2O$	372.59	57 123
$Ce(NH_4)_2(NO_3)_6$	548.23	73 896
$Ce(NH_4)_2(NO_3)_6\cdot 2H_2O$	584.26	76 661
$Ce(NH_4)_4(SO_4)_4\cdot 2H_2O$	632.55	80 109
$Ce(NO_3)_3$	326.13	51 339
$Ce(NO_3)_3\cdot 6H_2O$	434.23	63 772
CeO_2	172.12	23 583
Ce_2O_3	328.24	51 619
Ce_3O_4	484.36	68 517
$CePO_4$	235.09	37 123
$Ce(SO_4)_2$	332.24	52 145
$Ce(SO_4)_2\cdot 4H_2O$	404.30	60 670

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Ce_2(SO_4)_3$	568.42	75 467
$Ce_2(SO_4)_3 \cdot 8H_2O$	712.55	85 282
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Cl	35.453	54 965
2Cl	70.906	85 068
3Cl	106.359	02 677
4Cl	141.812	15 171
5Cl	177.27	24 864
6Cl	212.72	32 781
ClO	51.452	71 140
ClO_2	67.452	82 899
ClO_3	83.451	92 143
ClO_4	99.451	99 761
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Co	58.9332	77 036
$^1/_3$Co	19.64440	29 324
$^1/_2$Co	29.46660	46 933
2Co	117.8664	07 139
3Co	176.7996	24 748
$CoBr_2$	218.741	33 993
$CoBr_2 \cdot 6H_2O$	326.833	51 433
$Co(C_2H_3O_2)_2 \cdot 4H_2O$ (acetate)	249.085	39 635
$Co(C_5H_5N)_4(SCN)_2$ (pyridine)	491.51	69 153
$Co_3(C_6H_5O_7)_2 \cdot 4H_2O$ (citrate)	627.066	79 731
$Co(C_7H_6O_2N)_2$ (anthranilate)	331.196	52 009
$Co(C_9H_6ON)_2 \cdot 2H_2O$ (hydroxyquinolate)	383.272	58 351
$Co(C_{10}H_6O_2N)_3 \cdot 2H_2O$ (α-nitroso-β-naphtholate)	611.458	78 637
$CoC_2O_4 \cdot 2H_2O$	182.984	26 241
$CoCl_2$	129.839	11 341
$CoCl_2 \cdot 6H_2O$	237.931	37 645
$CoCrO_4$	174.927	24 286
$CoHg(SCN)_4$	491.85	69 183
$Co(NO_3)_2$	182.943	26 232
$Co(NO_3)_2 \cdot 6H_2O$	291.035	46 395
CoO	74.9326	87 467
Co_2O_3	165.8646	21 975
Co_3O_4	240.797	38 165

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Co_2P_2O_7$	291.810	46 510
CoS	90.997	95 904
$CoSO_4$	154.995	19 032
$CoSO_4 \cdot 7H_2O$	281.102	44 886
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Cr	51.996	71 597
$^1/_3Cr$	17.3320	23 885
2Cr	103.992	01 700
3Cr	155.988	19 309
$CrCl_2$	122.902	08 956
$CrCl_3$	158.355	19 963
$CrCl_3 \cdot 6H_2O$	266.447	42 561
$CrK(SO_4)_2 \cdot 12H_2O$	*See* $KCr(SO_4)_2 \cdot 12H_2O$	
$Cr(NO_3)_3$	238.011	37 660
$Cr(NO_3)_3 \cdot 9H_2O$	400.149	60 222
CrO	67.995	83 248
CrO_3	99.994	99 997
CrO_4	115.994	06 444
$^1/_3CrO_4$	38.6647	58 731
Cr_2O_3	151.990	18 182
$^1/_2Cr_2O_3$	75.995	88 079
Cr_2O_7	215.988	33 443
$^1/_6Cr_2O_7$	35.9980	55 628
$Cr(OH)_3$	103.018	01 291
$CrPO_4$	146.967	16 722
$Cr_2(SO_4)_3$	392.18	59 349
$Cr_2(SO_4)_3 \cdot 18H_2O$	716.45	85 519
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Cs	132.905	12 354
2Cs	265.810	42 457
$CsAl(SO_4)_2 \cdot 12H_2O$	568.19	75 449
Cs_2CO_3	325.819	51 298
CsCl	168.358	22 623
$CsClO_4$	232.356	36 615
Cs_2CrO_4	381.804	58 184
$Cs_2Cr_2O_7$	481.798	68 287
CsI	259.809	41 465
$CsNO_3$	194.910	28 983
Cs_2O	281.809	44 995
CsOH	149.912	17 584

Table 6 (continued)

Formula	Weight, *a*	log *a*
Cs_2PtCl_6	673.62	82 842
Cs_2SO_4	361.872	55 856
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Cu	63.546	80 309
$^1/_2Cu$	31.7730	50 206
2Cu	127.092	10 412
3Cu	190.638	28 021
$CuBr_2$	223.354	34 899
$Cu(C_2H_3O_2)_2 \cdot H_2O$ (acetate)	199.651	30 027
$Cu(C_5H_5N)_2(SCN)_2$ (pyridine)	337.91	52 880
$Cu(C_7H_6O_2N)_2$ (salicylaldoximate or anthranilate)	335.809	52 609
$Cu(C_9H_6ON)_2$ (hydroxyquinolate)	351.855	54 636
$Cu(C_{10}H_6O_2N)_2 \cdot H_2O$ (quinaldinate)	425.891	62 930
$Cu(C_{12}H_{10}ONS)_2 \cdot H_2O$ (thionalide)	514.13	71 107
$CuC_{14}H_{11}O_2N_2$ (cupron)	288.796	46 059
$CuCN$	89.564	95 213
$CuCl$	98.999	99 563
$CuCl_2$	134.452	12 857
$CuCl_2 \cdot 2H_2O$	170.483	23 168
$CuHg(SCN)_4$	496.46	69 588
CuI	190.450	27 978
$Cu(NO_3)_2$	187.556	27 313
$Cu(NO_3)_2 \cdot 3H_2O$	241.602	38 310
$Cu(NO_3)_2 \cdot 6H_2O$	295.648	47 077
CuO	79.545	90 061
$^1/_2CuO$	39.773	59 959
$Cu(OH)_2$	97.561	98 928
Cu_2O	143.091	15 561
$Cu_2(OH)_2CO_3$	221.116	34 462
CuS	95.610	98 050
Cu_2S	159.16	20 183
$CuSCN$	121.628	08 503
$CuSO_4$	159.608	20 305
$CuSO_4 \cdot 5H_2O$	249.685	39 739
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, a	log a
F	18.9984	27 872
2F	37.9968	57 974
3F	56.9952	75 584
4F	75.9936	88 078
5F	94.9920	97 769
6F	113.9904	05 687
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Fe	55.847	74 700
$^1/_3$Fe	18.616	26 989
$^1/_2$Fe	27.924	44 598
2Fe	111.69	04 801
3Fe	167.54	22 412
$FeBr_3$	295.559	47 064
$FeBr_3 \cdot 6H_2O$	403.651	60 601
Fe_3C	179.55	25 419
$Fe(C_9H_6ON)_3$ (hydroxyquinolate)	488.310	68 870
$Fe(CN)_6$	211.954	32 624
$FeCO_3$	115.856	06 392
$FeCl_2$	126.75	10 295
$FeCl_2 \cdot 4H_2O$	198.81	29 844
$FeCl_3$	162.21	21 008
$FeCl_3 \cdot 6H_2O$	270.30	43 185
$Fe(HCO_3)_2$	177.881	25 013
$FeNH_4(SO_4)_2 \cdot 12H_2O$	482.19	68 322
$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	392.14	59 344
$Fe(NO_3)_3$	241.862	38 357
$Fe(NO_3)_3 \cdot 6H_2O$	349.95	54 401
FeO	71.846	85 640
Fe_2O_3	159.69	20 328
$^1/_6Fe_2O_3$	26.615	42 513
$^1/_2Fe_2O_3$	79.846	90 225
Fe_3O_4	231.54	36 463
$Fe(OH)_3$	106.869	02 885
$FePO_4$	150.818	17 845
FeS	87.91	94 404
FeS_2	119.98	07 911
$FeSO_4$	151.91	18 159
$FeSO_4 \cdot 7H_2O$	278.02	44 408
$Fe_2(SO_4)_3$	399.88	60 193
$Fe_2(SO_4)_3 \cdot 9H_2O$	562.02	74 975
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, *a*	log *a*
Ga	69.72	84 336
2Ga	139.44	14 439
$Ga(C_9H_6ON)_3$ . . . . (hydroxyquinolate)	502.18	70 086
$Ga(C_9H_4Br_2ON)_3$ . . . . (bromohydroxyquinolate)	975.55	98 925
$GaCl_3$	176.08	24 571
Ga_2O_3	187.44	27 286
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ge	72.59	86 088
2Ge	145.18	16 191
$GeCl_4$	214.40	33 122
GeO_2	104.59	01 949
GeS_2	136.72	13 583
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
H	1.00797	00 345
2H	2.01594	30 448
3H	3.02391	48 057
4H	4.03188	60 551
5H	5.0399	70 242
6H	6.0478	78 160
7H	7.0558	84 855
8H	8.0638	90 654
H_3AsO_4	141.9431	15 211
$HAuCl_4 \cdot 4H_2O$	411.848	61 474
HBO_2	43.818	64 165
H_3BO_3	61.833	79 122
HBr	80.912	90 801
HBrO	96.911	98 637
$HBrO_3$	128.910	11 029
$HCHO_2$ . . . . (formic acid)	46.0259	66 300
$HC_2H_3O_2$ . . . . (acetic)	60.0530	77 853
$HC_3H_5O_3$ . . . . (lactic)	90.0795	95 463
$HC_4H_4O_6$ . . . . (hydrotartrate-ion)	149.081	17 342
$H_2C_4H_4O_4$ . . . . (succinic)	118.090	07 221
$H_2C_4H_4O_5$ . . . . (malic)	134.089	12 739
$H_2C_4H_4O_6$ . . . . (tartaric)	150.089	17 635

Table 6 (continued)

Formula	Weight, *a*	log *a*
$H_3C_6H_5O_7$ (citric)	192.126	28 358
$H_3C_6H_5O_7 \cdot H_2O$	210.142	32 251
$HC_6H_6O_3NS$ (sulphanilic)	173.192	23 853
$HC_6H_6O_3NS \cdot 2H_2O$	209.222	32 061
$HC_7H_5O_2$ (benzoic)	122.125	08 680
$HC_7H_5O_3$ (salicylic)	138.124	14 027
$HC_7H_6O_2N$ (anthranilic)	137.139	13 716
$HC_8H_4O_4$ (hydrophthalate-ion)	165.127	21 782
$H_2C_8H_4O_4$ (phthalic)	166.135	22 046
$H_2C_7H_4O_6S$ (sulphosalicylic)	218.186	33 882
$H_2C_7H_4O_6S \cdot 2H_2O$	254.217	40 520
$HC_{10}H_6O_2N$ (quinaldinic)	173.173	23 848
$HC_{10}H_6O_2N \cdot 2H_2O$	209.203	32 057
$H_4C_{10}H_{12}O_8N_2$ (ethylenediaminetetraacetic, complexone II)	292.248	46 575
HCN	27.0258	43 178
HCO_2	45.0179	65 339
$2HCO_2$	90.036	95 442
$3HCO_2$	135.054	13 051
HCO_3	61.0173	78 545
H_2CO_3	62.0253	79 257
$H_2C_2O_4$ (oxalic)	90.036	95 442
$H_2C_2O_4 \cdot 2H_2O$	126.067	10 060
$^1/_2H_2C_2O_4 \cdot 2H_2O$	63.0333	79 957
HCl	36.461	56 183
$HClO$	52.460	71 983
$HClO_3$	84.459	92 665
$HClO_4$	100.459	00 199
H_2CrO_4	118.010	07 192
$H_2Cr_2O_7$	218.004	33 846
HF	20.0064	30 117
HI	127.9124	10 691
HIO	143.9118	15 810
HIO_3	175.9106	24 529
HIO_4	191.9100	28 310
H_5IO_6	227.941	35 782
$H_2MoO_4 \cdot H_2O$	179.97	25 520
HNO_2	47.0135	67 222

Table 6 (continued)

Formula	Weight, *a*	log *a*
HNO_3	63.0129	79 943
HO *see* OH		
H_2O	18.0153	25 564
$2H_2O$	36.0307	55 667
$3H_2O$	54.0460	73 276
$4H_2O$	72.0614	85 770
$5H_2O$	90.077	95 461
$6H_2O$	108.092	03 379
$7H_2O$	126.107	10 074
$8H_2O$	144.123	15 873
H_2O_2	34.0147	53 167
$\frac{1}{2}H_2O_2$	17.0074	23 064
$2H_2O_2$	68.0295	83 270
HPO_3	79.9800	90 298
HPO_4	95.9794	98 218
H_2PO_4	96.9873	98 671
H_3PO_2	65.9965	81 952
H_3PO_3	81.9959	91 379
H_3PO_4	97.9953	99 121
$H_4P_2O_7$	177.975	25 036
$HReO_4$	251.2	40 002
HS *see* SH		
H_2S	34.080	53 250
$\frac{1}{2}H_2S$	17.040	23 147
HSCN	59.090	77 151
HSO_3	81.070	90 886
$2HSO_3$	162.14	20 989
H_2SO_3	82.078	91 423
HSO_4	97.070	98 709
H_2SO_4	98.078	99 157
$\frac{1}{2}H_2SO_4$	49.039	69 054
$2H_2SO_4$	196.16	29 261
$H_2S_2O_3$	114.14	05 744
H_2SO_5	114.077	05 720
H_2Se	80.98	90 838
H_2SeO_3	128.97	11 049
H_2SeO_4	144.97	16 128
H_2Te	129.62	11 267
H_2TeO_4	193.63	28 697
H_6TeO_6	229.64	36 105
H_2WO_4	249.86	39 770
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, *a*	log *a*
Hg	200.59	30 231
$^1/_2$Hg	100.295	00 128
2Hg	401.18	60 334
$HgBr_2$	360.40	55 678
$Hg(C_2H_3O_2)_2$ (acetate)	318.68	50 335
$Hg(C_5H_5N)_2Cr_2O_7$ (pyridine)	574.78	75 950
$Hg(C_7H_6O_2N)_2$ (anthranilate)	472.85	67 472
$Hg(C_{12}H_{10}ONS)_2$ (thionalide)	633.16	80 151
HgC_2O_4 (oxalate)	288.61	46 031
$Hg(CN)_2$	252.63	40 248
$HgCl_2$	271.50	43 377
Hg_2Cl_2	472.09	67 402
$HgCrO_4$	316.58	50 048
HgI_2	454.40	65 744
$Hg(NO_3)_2$	324.60	51 135
$Hg(NO_3)_2 \cdot H_2O$	342.62	53 481
$Hg_2(NO_3)_2$	525.19	72 032
$Hg_2(NO_3)_2 \cdot 2H_2O$	561.22	74 913
HgO	216.59	33 564
Hg_2O	417.18	62 032
HgS	232.65	36 670
Hg_2S	433.24	63 673
$Hg(SCN)_2$	316.75	50 072
$Hg_2(SCN)_2$	517.34	71 378
$HgSO_4$	296.65	47 224
Hg_2SO_4	497.24	69 657
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
I	126.9044	10 348
2I	253.8088	40 451
3I	380.7132	58 060
4I	507.6176	70 554
5I	634.5220	80 245
6I	761.4264	88 163
ICl	162.357	21 047
ICl_3	233.263	36 785
IO	142.9038	15 504
IO_3	174.9026	24 280
$^1/_6IO_3$	29.1504	46 464
IO_4	190.9020	28 081
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, *a*	log *a*
In	114.82	06 002
$^1/_3$In	38.273	58 289
2In	229.64	36 105
$In(C_9H_6ON)_3$ (hydroxyquinolate)	547.28	73 821
$InCl_3$	221.18	34 475
In_2O_3	277.64	44 348
$InPO_4$	209.79	32 178
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ir	192.2	28 375
$^1/_4$Ir	48.05	68 169
$^1/_2$Ir	96.10	98 272
$IrCl_3$	298.6	47 509
$IrCl_4$	334.0	52 375
$IrCl_6$	404.9	60 735
IrO_2	224.2	35 064
$Ir(OH)_3$	243.2	38 596
$Ir(OH)_4$	260.2	41 531
IrS	224.3	35 083
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
K	39.102	59 220
2K	78.204	89 323
3K	117.306	06 932
4K	156.408	19 426
5K	195.510	29 117
6K	234.612	37 035
$KAl(SO_4)_2 \cdot 12H_2O$	474.39	67 614
$KAlSi_3O_8$	278.337	44 457
KBF_4	125.907	10 005
KBr	119.006	07 557
$KBrO_3$	167.004	22 273
$^1/_6KBrO_3$	27.834	44 458
$KC_2H_3O_2$ (acetate)	98.147	99 187
$K_2C_4H_4O_6 \cdot {}^1/_2H_2O$ (tartrate)	235.285	37 159
$K(C_6H_5)_4B$	358.340	55 430
$K_3C_6H_5O_7 \cdot H_2O$ (citrate)	324.424	51 111
KCN	65.120	81 371
K_2CO_3	138.213	14 055
$K_2C_2O_4 \cdot H_2O$	184.239	26 538
KCl	74.555	87 248

Table 6 (continued)

Formula	Weight, *a*	log *a*
$KClO_3$	122.553	08 832
$^1/_6KClO_3$	20.426	31 018
$KClO_4$	138.553	14 162
$K_3Co(NO_2)_6$	452.272	65 540
$K_2Co(SO_4)_2 \cdot 6H_2O$	437.35	64 083
K_2CrO_4	194.198	28 824
$^1/_3K_2CrO_4$	64.733	81 113
$K_2Cr_2O_7$	294.192	46 863
$^1/_6K_2Cr_2O_7$	49.032	69 048
$^1/_2K_2Cr_2O_7$	147.096	16 760
$KCr(SO_4)_2 \cdot 12H_2O$	499.41	69 846
KF	58.100	76 418
$K_3Fe(CN)_6$	329.26	51 754
$K_4Fe(CN)_6$	368.36	56 627
$K_4Fe(CN)_6 \cdot 3H_2O$	422.41	62 573
$KFe(SO_4)_2 \cdot 12H_2O$	503.26	70 179
KH_2AsO_4	180.037	25 536
K_2HAsO_4	218.131	33 872
$KHC_4H_4O_6$ (hydrotartrate)	188.183	27 458
$KHC_8H_4O_4$ (hydrophthalate)	204.229	31 012
$KHCO_3$	100.119	00 052
$KHC_2O_4 \cdot H_2O$	146.145	16 478
$KH_3(C_2O_4)_2 \cdot 2H_2O$	254.196	40 517
KHF_2	78.107	89 269
$KH(IO_3)_2$	389.915	59 097
$^1/_{12}KH(JO_3)_2$	32.4929	51 179
KH_2PO_2	104.091	01 741
KH_2PO_4	136.089	13 382
K_2HPO_4	174.183	24 101
$KHSO_3$	120.172	07 980
$KHSO_4$	136.172	13 409
KI	166.006	22 012
KI_3	419.815	62 306
KIO_3	214.005	33 042
$^1/_6KIO_3$	35.6674	55 227
KIO_4	230.004	36 174
$KMnO_4$	158.038	19 876
$^1/_5KMnO_4$	31.6075	49 979
$^1/_3KMnO_4$	52.6792	72 164
$2KMnO_4$	316.075	49 979
$KN(C_6H_2)_2(NO_2)_6$ (dipicrylaminate)	477.307	67 880
KNO_2	85.108	92 997
KNO_3	101.107	00 478

Table 6 (continued)

Formula	Weight, *a*	log *a*
$KNaC_4H_4O_6 \cdot 4H_2O$	282.226	45 060
K_2O	94.203	97 406
$^1/_2K_2O$	47.102	67 304
$KOCN$	81.119	90 913
KOH	56.109	74 903
K_3PO_4	212.277	32 690
K_2PtCl_6	486.01	68 665
$KReO_4$	289.3	46 135
K_2S	110.268	04 245
$K_2S \cdot 5H_2O$	200.345	30 178
$KSCN$	97.184	98 759
K_2SO_3	158.266	19 939
$K_2SO_3 \cdot 2H_2O$	194.297	28 847
K_2SO_4	174.266	24 121
$K_2S_2O_5$	222.33	34 700
$K_2S_2O_7$	254.33	40 540
$K_2S_2O_8$	270.33	43 189
$K(SbO)C_4H_4O_6 \cdot {}^1/_2H_2O$ (tartrate)	333.93	52 366
K_2SiF_6	220.280	34 298
K_2TiF_6	240.09	38 037
K_2WO_4	326.05	51 328
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
La	138.91	14 273
$^1/_3La$	46.303	66 561
$2La$	277.82	44 376
$La(C_2H_3O_2)_3 \cdot 1^1/_2H_2O$	343.07	53 538
$LaCl_3 \cdot 7H_2O$	371.38	56 982
LaF_3	195.91	29 206
$La(NO_3)_3 \cdot 6H_2O$	433.02	63 651
La_2O_3	325.82	51 298
$La_2(SO_4)_3$	566.00	75 282
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Li	6.939	84 130
$2Li$	13.878	14 233
$3Li$	20.817	31 842
$LiBr$	86.843	93 873
$Li_3C_6H_5O_7 \cdot 4H_2O$ (citrate)	281.981	45 022
Li_2CO_3	73.887	86 857
$LiCl$	42.392	62 728
LiF	25.937	41 392

Table 6 (continued)

Formula	Weight, *a*	log *a*
LiH	7.947	90 020
LiI	133.843	12 660
$LiI \cdot 3H_2O$	187.889	27 390
$LiNO_3$	68.944	83 850
$LiNO_3 \cdot 3H_2O$	122.990	08 987
Li_2O	29.877	47 534
$LiOH$	23.946	37 923
Li_3PO_4	115.788	06 366
Li_2SO_4	109.940	04 116
$Li_2SO_4 \cdot H_2O$	127.955	10 706
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Mg	24.305	38 570
$^1/_2Mg$	12.1525	08 466
$2Mg$	48.610	68 673
$3Mg$	72.915	86 282
$Mg_2As_2O_7$	310.449	49 199
$MgBr_2$	184.113	26 508
$MgBr_2 \cdot 6H_2O$	292.205	46 569
$Mg(C_9H_6ON)_2$ (hydroxyquinolate)	312.614	49 501
$Mg(C_9H_6ON)_2 \cdot 2H_2O$	348.644	54 238
$MgCO_3$	84.314	92 590
$MgCl_2$	95.211	97 869
$MgCl_2 \cdot 6H_2O$	203.303	30 814
$Mg(ClO_4)_2$	223.206	34 871
$Mg(ClO_4)_2 \cdot 6H_2O$	331.298	52 022
MgF_2	62.302	79 450
$Mg(HCO_3)_2$	146.340	16 536
$MgNH_4AsO_4 \cdot 6H_2O$	289.355	46 143
$MgNH_4PO_4 \cdot 6H_2O$	245.407	38 988
$Mg(NO_3)_2$	148.315	17 119
$Mg(NO_3)_2 \cdot 6H_2O$	256.407	40 893
MgO	40.304	60 535
$^1/_2MgO$	20.152	30 432
$Mg(OH)_2$	58.320	76 582
$Mg_2P_2O_7$	222.553	34 743
$MgSO_4$	120.367	08 051
$MgSO_4 \cdot 7H_2O$	246.474	39 177
$MgSiO_3$	100.389	00 169
Mg_2SiO_4	140.694	14 828
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, *a*	log *a*
Mn	54.9381	73 987
$^1/_2Mn$	27.46905	43 884
$2Mn$	109.8762	04 090
$3Mn$	164.8143	21 699
$Mn(C_2H_3O_2)_2\cdot4H_2O$ . . . . (acetate)	245.089	38 932
$Mn(C_5H_5N)_4(SCN)_2$ . . . . (pyridine)	487.51	68 798
$MnCO_3$	114.9475	06 050
$MnCl_2$	125.844	09 983
$MnCl_2\cdot4H_2O$	197.905	29 646
$MnNH_4PO_4\cdot H_2O$	185.956	26 941
$Mn(NO_3)_2$	178.948	25 273
$Mn(NO_3)_2\cdot6H_2O$	287.040	45 794
MnO	70.9375	85 088
MnO_2	86.9369	93 920
MnO_4	118.9357	07 531
Mn_2O_3	157.8744	19 831
Mn_3O_4	228.8119	35 948
$Mn(OH)_2$	88.9528	94 916
$Mn_2P_2O_7$	283.820	45 304
MnS	87.002	93 953
$MnSO_4$	151.000	17 898
$MnSO_4\cdot4H_2O$	223.061	34 842
$MnSO_4\cdot5H_2O$	241.076	38 215
$MnSO_4\cdot7H_2O$	277.107	44 265
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Mo	95.94	98 200
$2Mo$	191.88	28 303
$3Mo$	287.82	45 912
MoO_3	143.94	15 818
MoO_4	159.94	20 396
$MoO_2(C_9H_6ON)_2$ . . . . (hydroxyquinolate)	416.25	61 935
MoS_2	160.07	20 431
MoS_3	192.13	28 360
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
N	14.0067	14 634
$2N$	28.0134	44 737
$3N$	42.0201	62 346
$4N$	56.0268	74 840
$5N$	70.0335	84 531

Table 6 (continued)

Formula	Weight, *a*	log *a*
6N	84.0402	92 449
5.55N ("gelatin")	77.7372	89 063
6.25N ("albumen")	87.5419	94 222
6.37N ("casein")	89.2227	95 048
NH	15.0147	17 652
NH_2	16.0226	20 473
$2NH_2$	32.0453	50 576
$3NH_2$	48.0679	68 186
NH_3	17.0306	23 123
$2NH_3$	34.0612	53 226
$3NH_3$	51.0918	70 835
$4NH_3$	68.1224	83 329
$5NH_3$	85.1531	93 020
$6NH_3$	102.1837	00 938
NH_4	18.0386	25 620
$2NH_4$	36.0772	55 723
$3NH_4$	54.1157	73 332
N_2H_4	32.0453	50 576
$N_2H_4 \cdot HCl$	68.506	83 573
$N_2H_4 \cdot 2HCl$	104.967	02 105
$N_2H_4 \cdot H_2O$	50.0606	69 950
$N_2H_4 \cdot H_2SO_4$	130.123	11 435
NH_2OH	33.0262	51 886
$NH_2OH \cdot HCl$	69.487	84 190
$(NH_2OH)_2 \cdot H_2SO_4$	164.138	21 521
NH_2SO_3H	97.093	98 719
$NH_4Al(SO_4)_2 \cdot 12H_2O$	453.33	65 642
NH_4Br	97.948	99 100
$NH_4C_2H_3O_2$ (acetate)	77.0836	88 696
$(NH_4)_2CO_3$	96.0865	98 266
$(NH_4)_2CO_3 \cdot H_2O$	114.102	05 729
$(NH_4)_2C_2O_4 \cdot H_2O$	142.112	15 263
$(NH_4)_2Ce(NO_3)_6$	548.23	73 896
$(NH_4)_4Ce(SO_4)_4 \cdot 2H_2O$	632.55	80 109
NH_4Cl	53.492	72 829
NH_4ClO_4	117.489	07 000
$(NH_4)_2CrO_4$	152.071	18 205
$(NH_4)_2Cr_2O_7$	252.065	40 151
NH_4F	37.0370	56 864
$NH_4Fe(SO_4)_2 \cdot 12H_2O$	482.19	68 322
$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$	392.11	59 341
NH_4HCO_3	79.0559	89 793
NH_4HF_2	57.0434	75 621
$NH_4H_2PO_4$	115.026	06 080
$(NH_4)_2HPO_4$	132.057	12 076

Table 6 (continued)

Formula	Weight, *a*	log *a*
NH_4HS	51.111	70 851
NH_4HSO_4	115.108	06 111
$(NH_4)_2Hg(SCN)_4$	468.99	67 116
NH_4I	144.9430	16 120
$(NH_4)_6Mo_7O_{24}\cdot 4H_2O$	1235.9	09 197
NH_4NO_2	64.0441	80 648
NH_4NO_3	80.0435	90 333
$NH_4NaHPO_4\cdot 4H_2O$	209.069	32 029
NH_4OH	35.0460	54 464
$(NH_4)_3PO_4\cdot 12MoO_3$	1876.3	27 330
$(NH_4)_2PdCl_6$	355.2	55 047
$(NH_4)_2PtCl_6$	443.89	64 728
$(NH_4)_2S$	68.141	83 341
NH_4SCN	76.120	88 150
$(NH_4)_2SO_3$	116.139	06 498
$(NH_4)_2SO_4$	132.139	12 103
$(NH_4)_2S_2O_8$	228.20	35 832
$(NH_4)_2SiF_6$	178.154	25 080
$(NH_4)_2SnCl_6$	367.49	56 525
NH_4VO_3	116.979	06 811
NO	30.0061	47 721
NO_2	46.0055	66 281
$2NO_2$	92.011	96 384
$3NO_2$	138.017	13 993
$4NO_2$	184.022	26 487
$5NO_2$	230.028	36 178
$6NO_2$	276.033	44 096
NO_3	62.0049	79 243
$2NO_3$	124.010	09 346
$3NO_3$	186.015	26 955
$4NO_3$	248.020	39 449
N_2O	44.0128	64 358
N_2O_3	76.0116	88 088
N_2O_4	92.011	96 384
N_2O_5	108.010	03 346
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Na	22.9898	36 154
$2Na$	45.9796	66 257
$3Na$	68.9694	83 866
$4Na$	91.9592	96 360
$5Na$	114.9490	06 051
$6Na$	137.9398	13 969
Na_3AlF_6	209.9413	32 210
$NaAlSi_3O_8$	262.225	41 867

Table 6 (continued)

Formula	Weight, *a*	log *a*
$NaAsO_2$	129.9102	11 364
$Na_3AsO_4 \cdot 12H_2O$	424.073	62 744
$NaB(C_6H_5)_4$	342.229	53 432
$NaBH_4$	37.833	57 787
$NaBO_2 \cdot 4H_2O$	137.861	13 944
$NaBO_3 \cdot 4H_2O$	153.860	18 713
$Na_2B_4O_7$	201.22	30 367
$^1/_2Na_2B_4O_7$	100.61	00 264
$Na_2B_4O_7 \cdot 10H_2O$	381.37	58 135
$^1/_2Na_3B_4O_7 \cdot 10H_2O$	190.69	28 033
$NaBiO_3$	279.968	44 711
$NaBr$	102.894	01 239
$NaBr \cdot 2H_2O$	138.925	14 278
$NaBrO_3$	150.892	17 867
$^1/_6NaBrO_3$	25.1487	40 052
$NaC_2H_3O_2$ (acetate)	82.0348	91 400
$NaC_2H_3O_2 \cdot 3H_2O$	136.081	13 380
$Na_2C_4H_4O_6 \cdot 2H_2O$ (tartrate)	230.083	36 188
$Na_3C_6H_5O_7 \cdot 5^1/_2H_2O$ (citrate)	357.156	55 286
$Na_2C_8H_4O_4$ (phthalate)	210.098	32 242
$NaCN$	49.0077	69 026
Na_2CO_3	105.9890	02 526
$^1/_2Na_2CO_3$	52.9945	72 423
$Na_2CO_3 \cdot 10H_2O$	286.142	45 658
$^1/_2Na_2CO_3 \cdot 10H_2O$	143.071	15 555
$Na_2C_2O_4$ (oxalate)	134.000	12 710
$^1/_2Na_2C_2O_4$	67.0000	82 607
$NaCl$	58.443	76 673
$NaClO$	74.442	87 182
$NaClO_3$	106.441	02 711
$NaClO_4$	122.440	08 792
$Na_3Co(NO_2)_6$	403.936	60 631
Na_2CrO_4	161.973	20 944
$Na_2CrO_4 \cdot 4H_2O$	234.035	36 928
$Na_2Cr_2O_7$	261.967	41 825
$Na_2Cr_2O_7 \cdot 2H_2O$	297.998	47 421
NaF	41.9882	62 313
$Na_4Fe(CN)_6 \cdot 10H_2O$	484.07	68 491
$Na_2[Fe(CN)_5NO] \cdot 2H_2O$ (nitroprussiate)	297.953	47 415
Na_2HAsO_3	169.9074	23 021

Table 6 (continued)

Formula	Weight, *a*	log *a*
Na_2HAsO_4	185.907	26 930
$Na_2HAsO_4\cdot 7H_2O$	312.014	49 417
$Na_2HAsO_4\cdot 12H_2O$	402.091	60 432
$NaHC_4H_4O_6$ (hydrotartrate)	172.071	23 571
$NaHC_8H_4O_4$ (hydrophthalate)	188.116	27 443
$Na_2H_2C_{10}H_{12}O_8N_2$ (ethylenediaminetetraacetate, complexone III, trilon B)	336.211	52 661
$Na_2H_2C_{10}H_{12}O_8N_2\cdot 2H_2O$ (ethylenediaminetetraacetate, dihydrate)	372.242	57 083
$NaHCO_3$	84.0071	92 432
$NaHC_2O_4$	112.018	04 929
$NaHC_2O_4\cdot H_2O$	130.033	11 405
NaH_2PO_2	87.9783	94 438
NaH_2PO_4	119.977	07 910
$NaH_2PO_4\cdot 2H_2O$	156.008	19 315
Na_2HPO_4	141.959	15 216
$Na_2HPO_4\cdot 2H_2O$	177.990	25 040
$Na_2HPO_4\cdot 12H_2O$	358.143	55 406
$NaHS$	56.062	74 867
$NaHSO_3$	104.060	01 728
$NaHSO_4$	120.059	07 939
$NaHSeO_3$	150.96	17 886
NaI	149.8942	17 578
$NaIO_3$	197.8924	29 643
$NaIO_4$	213.892	33 019
$NaKC_4H_4O_6\cdot 4H_2O$ (tartrate)	282.226	45 060
$NaMg(UO_2)_3(C_2H_3O_2)_9\cdot 6H_2O$	1496.88	17 518
Na_2MoO_4	205.92	31 370
$Na_2MoO_4\cdot 2H_2O$	241.95	38 373
NaN_3	65.0099	81 298
$NaNH_2$	39.0124	59 120
$NaNH_4HPO_4$	137.008	13 675
$NaNH_4HPO_4\cdot 4H_2O$	209.069	32 029
$NaNO_2$	68.9953	83 882
$NaNO_3$	84.9947	92 939
Na_2O	61.9790	79 224
$^1/_2Na_2O$	30.9895	49 121
Na_2O_2	77.9784	89 197
$NaOH$	39.9972	60 203
$NaPO_3$	101.9618	00 844
Na_3PO_4	163.941	21 469
$Na_3PO_4\cdot 12H_2O$	380.125	57 993

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Na_4P_2O_7$	265.903	42 472
$Na_4P_2O_7 \cdot 10H_2O$	446.056	64 939
Na_2S	78.044	89 234
$Na_2S \cdot 9H_2O$	240.182	38 054
$NaSCN$	81.072	90 887
Na_2SO_3	126.042	10 051
$Na_2SO_3 \cdot 7H_2O$	252.149	40 166
Na_2SO_4	142.041	15 241
$Na_2SO_4 \cdot 10H_2O$	322.195	50 812
$Na_2S_2O_3$	158.11	19 896
$^1/_2 Na_2S_2O_3$	79.053	89 792
$Na_2S_2O_3 \cdot 5H_2O$	248.18	39 477
$^1/_2 Na_2S_2O_3 \cdot 5H_2O$	124.091	09 374
$Na_2S_2O_4$	174.11	24 082
$Na_2S_2O_4 \cdot 2H_2O$	210.14	32 251
$Na_2S_2O_5$	190.10	27 898
$Na_2S_2O_8$	238.10	37 676
$Na_3SbS_4 \cdot 9H_2O$	481.11	68 224
Na_2SeO_3	172.94	23 790
Na_2SiF_6	188.056	27 429
Na_2SiO_3	122.064	08 659
$Na_2SnO_3 \cdot 3H_2O$	266.71	42 604
$Na_2U_2O_7$	634.04	80 212
$Na_2U_2O_7 \cdot 6H_2O$	742.13	87 048
$NaVO_3 \cdot 4H_2O$	193.991	28 778
Na_2WO_4	293.81	46 807
$Na_2WO_4 \cdot 2H_2O$	329.84	51 830
$NaZn(UO_2)_3(C_2H_3O_2)_9 \cdot 6H_2O$	1537.94	18 694
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Nb	92.906	96 804
$2Nb$	185.812	26 907
$NbCl_5$	270.17	43 164
Nb_2O_5	265.809	42 457
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ni	58.71	76 871
$^1/_2 Ni$	29.355	46 768
$2Ni$	117.42	06 974
$Ni(C_2H_3O_2)_2 \cdot 4H_2O$ (acetate)	248.86	39 596
$Ni(C_4H_7O_2N_2)_2$ (dimethylglyoximate)	288.94	46 081

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Ni(C_5H_5N)_4(SCN)_2$ . . . . (pyridine)	491.28	69 133
$Ni(C_7H_6O_2N)_2$ . . . . (anthranilate)	330.97	51 979
$Ni(C_9H_6ON)_2$ . . . . (hydroxyquinolate)	347.02	54 035
$Ni(C_9H_6ON)_2 \cdot 2H_2O$	383.05	58 326
$NiCO_3$	118.72	07 452
$Ni(CO)_4$	170.75	23 236
$NiCl_2 \cdot 6H_2O$	237.71	37 605
$NiCl_2$	129.62	11 267
$Ni(NO_3)_2$	182.72	26 179
$Ni(NO_3)_2 \cdot 6H_2O$	290.81	46 361
$Ni(NH_4)_2(SO_4)_2 \cdot 6H_2O$	395.00	59 660
NiO	74.71	87 338
Ni_2O_3	165.42	21 859
$Ni_2P_2O_7$	291.36	46 443
NiS	90.77	95 794
$NiSO_4$	154.77	18 969
$NiSO_4 \cdot 7H_2O$	280.88	44 852
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
O	15.9994	20 410
$^1/_2$O	7.9997	90 307
2O	31.9988	50 513
3O	47.9982	68 122
4O	63.9976	80 616
5O	79.997	90 307
6O	95.996	98 225
7O	111.996	04 920
8O	127.995	10 719
OCH_3	31.0345	49 184
OC_2H_5	45.0616	65 381
OCN	42.0173	62 343
OH	17.0074	23 064
2OH	34.0147	53 167
3OH	51.0221	70 776
4OH	68.0295	83 270
5OH	85.037	92 961
6OH	102.044	00 879
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Os	190.2	27 921
2Os	380.4	58 024

Table 6 (continued)

Formula	Weight, *a*	log *a*
$OsCl_4$	332.0	52 114
OsO_2	222.2	34 674
OsO_4	254.2	40 518
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
P	30.9738	49 099
$^1/_5P$	6.19476	79 202
$^1/_3P$	10.32460	01 387
2P	61.9476	79 202
3P	92.9214	96 812
PBr_3	270.686	43 247
PCl_3	137.333	13 777
PCl_5	208.24	31 856
PH_3	33.9977	53 145
PO_2	62.9726	79 915
PO_3	78.9720	89 747
PO_4	94.9714	97 759
$2PO_4$	189.943	27 862
P_2O_3	109.9458	04 118
P_2O_5	141.945	15 212
P_2O_7	173.943	24 041
$POCl_3$	153.332	18 563
$P_2O_5 \cdot 24MoO_3$	3596.5	55 588
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Pb	207.19	31 637
$^1/_2Pb$	103.595	01 534
2Pb	414.38	61 740
3Pb	621.57	79 349
$PbBr_2$	367.00	56 467
$Pb(C_2H_3O_2)_2$ (acetate)	325.28	51 226
$Pb(C_2H_3O_2)_2 \cdot 3H_2O$	379.33	57 902
$Pb(C_2H_5)_4$	323.44	50 979
$Pb(C_7H_4NS_2)OH$ (mercaptobenzothiazolide)	390.44	59 155
$Pb(C_7H_6O_2N)_2$ (salicylaldoximate or anthranilate)	479.45	68 074
$Pb(C_{10}H_7O_5N_4)_2 \cdot 1^1/_2H_2O$ (picrolonate)	760.60	88 116
$Pb(C_{12}H_{10}ONS)_2$ (thionalide)	639.75	80 602
$PbCO_3$	267.20	42 684
$PbCl_2$	278.10	44 420

Table 6 (continued)

Formula	Weight, *a*	log *a*
$PbCl_4$	349.00	54 283
$PbClF$	261.64	41 770
$PbCrO_4$	323.18	50 944
PbF_2	245.19	38 950
PbI_2	461.00	66 370
$PbMoO_4$	367.13	56 482
$Pb(NO_3)_2$	331.20	52 009
PbO	223.19	34 867
PbO_2	239.19	37 874
Pb_3O_4	685.57	83 605
$Pb(OH)_2$	241.20	38 238
PbS	239.25	37 885
$PbSO_3$	287.25	45 826
$PbSO_4$	303.25	48 180
$PbWO_4$	455.04	65 805
. . . .	. . . .	. . . . . .
. . . .	. . . .	. . . .
Pd	106.4	02 694
2Pd	212.8	32 797
$Pd(C_4H_7O_2N_2)_2$ (dimethylglyoximate)	336.6	52 711
$Pd(C_7H_6O_2N)_2$ (salicylaldoximate)	378.7	57 830
$Pd(C_9H_6ON)_2$ (hydroxyquinolate)	394.7	59 627
$Pd(CN)_2$	158.4	19 976
$PdCl_2$	177.3	24 871
$PdCl_2 \cdot 2H_2O$	213.3	32 899
$PdCl_4$	248.2	39 480
$PdCl_6$	319.1	50 393
PdI_2	360.2	55 654
$Pd(NO_3)_2$	230.4	36 248
PdO	122.4	08 778
PdS	138.5	14 145
$PdSO_4$	202.5	30 643
$PdSO_4 \cdot 2H_2O$	238.5	37 749
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Pt	195.09	29 024
$^{1}/_{4}Pt$	48.773	68 818
$^{1}/_{2}Pt$	97.545	98 921
2Pt	390.18	59 127
$PtCl_4$	336.90	52 750
$PtCl_6$	407.81	61 046
PtS	227.15	35 631

Table 6 (continued)

Formula	Weight, *a*	log *a*
Rb	85.47	93 181
2Rb	170.94	23 284
$RbAl(SO_4)_2 \cdot 12H_2O$	520.76	71 664
Rb_2CO_3	230.95	36 352
RbCl	120.92	08 250
$RbClO_4$	184.92	26 698
RbI	212.37	32 709
$RbNO_3$	147.47	16 870
Rb_2O	186.94	27 170
Rb_2PtCl_6	578.75	76 249
Rb_2SO_4	267.00	42 651
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Re	186.2	26 998
2Re	372.4	57 101
$ReCl_3$	292.6	46 627
$ReCl_5$	363.5	56 050
ReO_2	218.2	33 885
ReO_3	234.2	36 959
ReO_4	250.2	39 829
Re_2O_7	484.4	68 520
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Rh	102.905	01 244
2Rh	205.810	31 347
$RhCl_3$	209.264	32 069
RhO_2	134.904	13 002
Rh_2O_3	253.808	40 451
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ru	101.07	00 462
2Ru	202.14	30 565
RuO_4	165.07	21 767
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
S	32.064	50 602
2S	64.13	80 706
3S	96.19	98 313
4S	128.26	10 809
5S	160.32	20 499
6S	192.38	28 416
SCN	58.082	76 404
2SCN	116.16	06 506

Table 6 (continued)

Formula	Weight, *a*	log *a*
$3SCN$	174.25	24 117
$4SCN$	232.33	36 611
$5SCN$	290.41	46 301
$6SCN$	348.49	54 219
SH	33.072	51 946
$2SH$	66.14	82 046
$3SH$	99.22	99 660
SO_2	64.063	80 661
SO_3	80.062	90 343
SO_3H	81.070	90 886
$2SO_3H$	162.14	20 989
SO_3Na	103.052	01 306
$2SO_3Na$	206.10	31 408
SO_4	96.062	98 255
$2SO_4$	192.12	28 357
$3SO_4$	288.18	45 966
S_2O_3	112.13	04 972
S_2O_4	128.13	10 765
S_2O_7	176.12	24 581
S_2O_8	192.12	28 357
S_4O_6	224.25	35 073
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Sb	121.75	08 547
$^1/_5Sb$	24.350	38 650
$^1/_3Sb$	40.583	60 834
$^1/_2Sb$	60.875	78 444
$2Sb$	243.50	38 650
$SbC_6H_5O_4$ . . . . (pyrogallate)	262.85	41 971
$Sb(C_9H_6ON)_3$ . . . . (hydroxyquinolate)	554.21	74 367
$Sb(C_{12}H_{10}ONS)_3$ . . . . (thionalide)	770.60	88 683
$SbCl_3$	228.11	35 814
$SbCl_5$	299.02	47 570
SbI_3	502.46	70 110
$SbOCl$	173.20	23 855
Sb_2O_3	291.50	46 464
Sb_2O_5	323.50	50 987
SbS_4	250.01	39 796
Sb_2S_3	339.69	53 108
Sb_2S_5	403.82	60 619
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 6 (continued)

Formula	Weight, *a*	log *a*
Sc	44.956	65 279
2Sc	89.912	95 382
Sc_2O_3	137.910	13 960
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Se	78.96	89 741
2Se	157.92	19 844
SeO_2	110.96	04 517
SeO_3	126.96	10 367
SeO_4	142.96	15 521
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Si	28.086	44 849
2Si	56.172	74 952
3Si	84.258	92 561
4Si	112.344	05 055
5Si	140.43	14 746
6Si	168.52	22 665
SiC	40.097	60 311
$SiCl_4$	169.90	23 019
SiF_4	104.080	01 737
SiF_6	142.076	15 252
SiH_4	32.118	50 675
SiO_2	60.085	77 877
SiO_3	76.084	88 129
$2SiO_3$	152.168	18 232
$3SiO_3$	228.253	35 842
$4SiO_3$	304.34	48 336
SiO_4	92.084	96 418
$2SiO_4$	184.167	26 521
Si_2O_7	168.168	22 574
Si_3O_8	212.253	32 685
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Sn	118.69	07 441
$^1/_4$Sn	29.673	47 236
$^1/_2$Sn	59.345	77 338
2Sn	237.38	37 544
$SnCl_2$	189.60	27 784
$SnCl_2 \cdot 2H_2O$	225.63	35 340
$SnCl_4$	260.50	41 581
SnO	134.69	12 934
SnO_2	150.69	17 808

Table 5 (continued)

Formula	Weight, *a*	log *a*
SnS	150.75	17 826
SnS_2	182.82	26 202
SnS_3	214.88	33 220
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Sr	87.62	94 260
$^1/_2$Sr	43.810	64 157
2Sr	175.24	24 363
$Sr(C_2H_3O_2)_2 \cdot {}^1/_2H_2O$ (acetate)	214.72	33 187
SrC_2O_4	175.64	24 462
$SrC_2O_4 \cdot H_2O$	193.66	28 704
$SrCO_3$	147.63	16 917
$SrCl_2$	158.53	20 011
$SrCl_2 \cdot 6H_2O$	266.62	42 589
$SrCrO_4$	203.61	30 880
$Sr(NO_3)_2$	211.63	32 558
$Sr(NO_3)_2 \cdot 4H_2O$	283.69	45 284
SrO	103.62	01 544
$Sr(OH)_2$	121.63	08 504
$Sr(OH)_2 \cdot 8H_2O$	265.76	42 449
$SrSO_3$	167.68	22 448
$SrSO_4$	183.68	26 406
SrS_2O_3	199.75	30 049
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ta	180.948	25 755
2Ta	361.896	55 858
$TaCl_5$	358.21	55 414
Ta_2O_5	441.893	64 532
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Te	127.60	10 585
2Te	255.20	40 688
TeO_2	159.60	20 303
TeO_3	175.60	24 452
TeO_4	191.60	28 240
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Th	232.038	36 556
2Th	464.076	66 659
$Th(C_9H_6ON)_4$ (hydroxyquinolate)	808.655	90 776

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Th(C_9H_6ON)_4 \cdot (C_9H_7ON)$ (hydroxyquinolate) (hydroxyquinoline)	953.817	97 947
$Th(C_{10}H_7O_5N_4)_4 \cdot H_2O$ (picrolonate)	1302.818	11 488
$Th(C_2O_4)_2 \cdot 6H_2O$ (oxalate)	516.170	71 279
$ThCl_4$	373.850	57 270
$Th(NO_3)_4$	480.058	68 129
$Th(NO_3)_4 \cdot 4H_2O$	552.119	74 203
$Th(NO_3)_4 \cdot 12H_2O$	696.242	84 276
ThO_2	264.037	42 166
$Th(SO_4)_2$	424.16	62 753
$Th(SO_4)_2 \cdot 9H_2O$	586.30	76 812
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Ti	47.90	68 034
$^1/_4Ti$	11.975	07 828
$^1/_3Ti$	15.967	20 322
$2Ti$	95.80	98 137
$TiCl_3$	154.26	18 825
$TiCl_4$	189.71	27 809
$TiO(C_9H_6ON)_2$ (hydroxyquinolate)	352.21	54 681
TiO_2	79.90	90 255
$(TiO)_2P_2O_7$	301.74	47 963
$TiOSO_4$	159.96	20 401
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Tl	204.37	31 042
$2Tl$	408.74	61 145
$TlBr$	284.27	45 373
$TlC_7H_4NS_2$ (mercaptobenzothiazolide)	370.61	56 892
$TlC_{12}H_{10}ONS$ (thionalide)	420.65	62 392
$TlCl$	239.82	37 989
Tl_2CrO_4	524.73	71 994
TlI	331.27	52 018
$TlNO_3$	266.37	42 549
Tl_2O	424.74	62 812
Tl_2O_3	456.74	65 967
$TlOH$	221.38	34 514
Tl_2PtCl_6	816.55	91 198
Tl_2S	440.80	64 424

Table 6 (continued)

Formula	Weight, *a*	log *a*
Tl_2SO_4	504.80	70 312
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
U	238.03	37 663
$^1/_6U$	39.672	59 848
$^1/_4U$	59.508	77 458
$2U$	476.06	67 766
$3U$	714.09	85 375
UCl_4	379.84	57 960
UF_4	314.02	49 696
UF_6	352.02	54 657
UO_2	270.03	43 141
$2UO_2$	540.06	73 244
UO_3	286.03	45 641
UO_4	302.03	48 005
U_3O_8	842.09	92 536
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
$UO_2(C_2H_3O_2)_2$ (acetate)	388.12	58 897
$UO_2(C_2H_3O_2)_2 \cdot 2H_2O$	424.15	62 752
$UO_2(C_9H_6ON)_2 \cdot (C_9H_7ON)$ (hydroxyquinolate) (hydroxyquinoline)	703.50	84 726
$UO_2(NO_3)_2$	394.04	59 554
$UO_2(NO_3)_2 \cdot 6H_2O$	502.13	70 082
$(UO_2)_3NaMg(C_2H_3O_2)_9 \cdot 6H_2O$	1496.88	17 518
$(UO_2)_3NaZn(C_2H_3O_2)_9 \cdot 6H_2O$	1537.94	18 694
$(UO_2)_2P_2O_7$	714.00	85 370
UO_2SO_4	366.09	56 359
$UO_2SO_4 \cdot 3H_2O$	420.14	62 339
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
V	50.942	70 708
$^1/_5V$	10.1884	00 810
$^1/_4V$	12.7355	10 502
$2V$	101.884	00 810
VCl_4	192.754	28 500
VO	66.941	82 569
$VOCl_2$	137.847	13 940
VO_2	82.941	91 877
VO_3	98.940	99 537
VO_4	114.940	06 047
V_2O_3	149.882	17 575

Table 6 (continued)

Formula	Weight, *a*	log *a*
$V_2O_3(C_9H_6ON)_4$ . . . . (hydroxyquinolate)	726.499	86 124
V_2O_5	181.881	25 979
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
W	183.85	26 446
2W	367.70	56 549
WC	195.86	29 195
WCl_5	361.12	55 765
$WO_2(C_9H_6ON)_2$ . . . . (hydroxyquinolate)	504.16	70 257
WO_3	231.85	36 521
WO_4	247.85	39 419
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Y	88.905	94 893
2Y	177.810	24 996
Y_2O_3	225.819	35 374
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Zn	65.37	81 538
$^1/_2$Zn	32.685	51 435
2Zn	130.74	11 641
3Zn	196.11	29 250
$Zn(C_2H_3O_2)_2$ . . . . (acetate)	183.46	26 354
$Zn(C_2H_3O_2)_2 \cdot 2H_2O$	219.49	34 141
$Zn(C_5H_5N)_2(SCN)_2$ . . . . (pyridine)	339.74	53 115
$Zn(C_7H_6O_2N)_2$ . . . . (anthranilate)	337.63	52 844
$Zn(C_9H_6ON)_2$ . . . . (hydroxyquinolate)	353.68	54 861
$Zn(C_{10}H_6O_2N)_2 \cdot H_2O$ . . . . . . (quinaldinate)	427.71	63 115
$Zn(CN)_2$	117.41	06 971
$ZnCO_3$	125.38	09 823
$ZnCl_2$	136.28	13 443
$ZnHg(SCN)_4$	498.29	69 748
$ZnNH_4PO_4$	178.38	25 135
$Zn(NO_3)_2$	189.38	27 733
$Zn(NO_3)_2 \cdot 6H_2O$	297.47	47 344
ZnO	81.37	91 046
$Zn(OH)_2$	99.38	99 730

Table 6 (continued)

Formula	Weight, *a*	log *a*
$Zn_3(PO_4)_2 \cdot 4H_2O$	458.11	66 097
$Zn_2P_2O_7$	304.68	48 384
ZnS	97.43	98 869
$ZnSO_4$	161.43	20 798
$ZnSO_4 \cdot 7H_2O$	287.54	45 870
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .
Zr	91.22	96 009
2Zr	182.44	26 112
$Zr(C_9H_6ON)_4$ (hydroxyquinolate)	667.84	82 467
$ZrCl_4$	233.03	36 741
$Zr(NO_3)_4$	339.24	53 051
$Zr(NO_3)_4 \cdot 5H_2O$	429.32	63 278
ZrO_2	123.22	09 068
$ZrOCl_2 \cdot 8H_2O$	322.25	50 819
ZrP_2O_7	265.16	42 351
$Zr(SO_4)_2$	283.34	45 231
$Zr(SO_4)_2 \cdot 4H_2O$	355.40	55 072
$ZrSiO_4$	183.30	26 316
. . . .	. . . .	. . . .
. . . .	. . . .	. . . .

Table 7

Analytical and Stoichiometric Multipliers (Factors)*

If g is the weighed portion of a substance taken for an analysis, a is the mass of a dried or calcined precipitate (gravimetric form) and f is the multiplier found in the given table, then the percentage of the unknown substance can be found according to the formula:

$$x=\frac{a\cdot f\cdot 100}{g}\ \%,\qquad \log x=\log a+\log f+2-\log g$$

where a and g are expressed in the same units.

Calculations must be made by discarding the characteristics of logarithms and leaving only the mantissas. Then, every calculation is reduced to the addition of three numbers

$$\log a+\log f+(1-\log g)$$

In this table, the multipliers and their logarithms occasionally do not exactly conform to one another because the multipliers are rounded, while the logarithms of the multipliers—the intermediate stage of calculations—are given in more accurate numbers.

Substance being determined	Weighed portion	Multiplier, f	$\log f$
Ag	AgBr	0.5745	75 926
	AgCl	0.7526	87 658
	AgI	0.4595	66 224
	. . . .	. . . . . .	. . . . . .
Al	$Al(C_9H_6ON)_3$ . . . . . . (hydroxyquinolate)	0.05873	76 883
	Al_2O_3	0.5293	72 367
	$AlPO_4$	0.2212	34 487
	. . . .	. . . . . .	. . . . . .
Ba	$BaCrO_4$	0.5421	73 411
	$BaSO_4$	0.5884	76 970
	. . . .	. . . . . .	. . . . . .
$BaCl_2$	$BaSO_4$	0.8923	95 049
$BaCl_2\cdot 2H_2O$	$BaSO_4$	1.0466	01 979
	. . . .	. . . . . .	. . . . . .
Be	BeO	0.3603	55 669
	. . . .	. . . . . .	. . . . .

---

* For the use of the table, see p. 460.

Table 7 (continued)

Substance being determined	Weighed portion	Multiplier, *f*	log *f*
Bi	$BiC_6H_3O_3$ (pyrogallate)	0.6293	79 887
	$Bi(C_9H_6ON)_3$ (hydroxyquinolate)	0.3258	51 294
	$Bi(C_{12}H_{10}ONS)_3 \cdot H_2O$ (thionalide)	0.2386	37 767
	Bi_2O_3	0.8970	95 279
	$BiOCl$	0.8024	90 441
	$BiPO_4$	0.6875	83 730
	. . . .	. . . . . .	. . . . . .
Br	$AgBr$	0.4255	62 894
	. . . .	. . . . . .	. . . . . .
C	CO_2	0.2729	43 603
	$BaCO_3$	0.06086	78 434
	. . . .	. . . . . .	. . . . . .
CN	$AgCN$	0.1943	28 853
	. . . .	. . . . . .	. . . . . .
CO_2	$BaCO_3$	0.2230	34 831
	$CaCO_3$	0.4397	64 316
	. . . .	. . . . . .	. . . . . .
CO_3	$BaCO_3$	0.3041	48 298
	. . . .	. . . . . .	. . . . . .
Ca	$CaCO_3$	0.4004	60 254
	$CaC_2O_4 \cdot H_2O$ (oxalate)	0.2743	43 822
	CaO	0.7147	85 412
	$CaSO_4$	0.2944	46 894
	. . . .	. . . . . .	. . . . . .
$CaCO_3$	CO_2	2.274	35 684
	CaO	1.785	25 158
	. . . .	. . . . . .	. . . . . .
Cd	$Cd(C_7H_4NS_2)_2$ (mercaptobenzothiazolide)	0.2527	40 252
	$Cd(C_7H_6O_2N)_2$ (anthranilate)	0.2922	46 569
	$Cd(C_9H_6ON)_2$ (hydroxyquinolate)	0.2805	44 794
	$Cd(C_{10}H_6O_2N)_2$ (quinaldinate)	0.2461	39 111
	CdO	0.8754	94 220
	$Cd_2P_2O_7$	0.5638	75 111
	. . . .	. . . . . .	. . . . . .

Table 7 (continued)

Substance being determined	Weighed portion	Multiplier, *f*	log *f*
Cl	AgCl	0.2474	39 334
ClO_3	AgCl	0.5823	76 512
ClO_4	AgCl	0.6939	84 130
Co	$Co_2P_2O_7$	0.4039	60 629
Cr	$BaCrO_4$	0.2053	31 228
CrO_4	$BaCrO_4$	0.4579	66 075
Cr_2O_7	$BaCrO_4$	0.4263	62 971
Cu	$Cu(C_5H_5N)_2(SCN)_2$ (pyridine)	0.1881	27 429
	$Cu(C_9H_6ON)_2$ (hydroxyquinolate)	0.1806	25 673
	$CuC_{14}H_{11}O_2N$ (cupron)	0.2200	34 250
	CuO	0.7989	90 248
F	CaF_2	0.4866	68 721
	PbClF	0.07261	86 102
Fe	Fe_2O_3	0.6994	84 473
H	H_2O	0.1119	04 884
HBr	AgBr	0.4309	63 438
HCN	AgCN	0.2019	30 504
HI	AgI	0.5448	73 626
HNO_3	$C_{20}H_{16}N_4 \cdot HNO_3$ (nitron)	0.1679	22 495

Table 7 (continued)

Substance being determined	Weighed portion	Multiplier, *f*	log *f*
H_3PO_4	$Mg_2P_2O_7$	0.8806	94 478
H_2SO_4	$BaSO_4$	0.4202	62 347
K	$K(C_6H_5)_4B$	0.1091	03 790
	KCl	0.5245	71 972
	$KClO_4$	0.2822	45 058
	$KN(C_6H_2)_3(NO_2)_6$ (dipicrylaminate)	0.08192	91 340
	K_2PtCl_6	0.1609	20 658
	K_2SO_4	0.4489	65 212
Li	Li_3PO_4	0.1798	25 476
Mg	$Mg(C_9H_6ON)_2$ (hydroxyquinolate)	0.07775	89 069
	$Mg_2P_2O_7$	0.2184	33 930
Mn	$Mn_2P_2O_7$	0.3871	58 786
Mo	MoO_3	0.6665	82 382
	$PbMoO_4$	0.2613	41 718
MoO_4	$PbMoO_4$	0.4357	63 914
N	Pt	0.1436	15 713
NH_4	Pt	0.1849	26 699
Na	Na_2SO_4	0.3237	51 016
	$NaZn(UO_2)_3 \cdot (C_2H_3O_2)_9 \times \times 6H_2O$	0.01495	17 460
Ni	$NiC_8H_{14}N_4O_4$ (dimethylglyoximate)	0.2032	30 790
	NiO	0.7858	89 533

Table 7 (continued)

Substance being determined	Weighed portion	Multiplier, *f*	log *f*
Ni	$NiSO_4$	0.3793	57 902
	. . . .	. . . . . .	. . . . . .
P	$Mg_2P_2O_7$	0.2783	44 456
	$(NH_4)_3PO_4 \cdot 12MoO_3$	0.01651 (theoretic)	21 769
		0.01639 (empiric)	21 464
	$P_2O_5 \cdot 24MoO_3$	0.01722	23 614
	. . . .	. . . . . .	. . . . . .
Pb	$PbCrO_4$	0.6411	80 693
	$PbMoO_4$	0.5644	75 155
	$PbSO_4$	0.6832	83 457
	. . . .	. . . . . .	. . . . . .
S	$BaSO_4$	0.1374	13 792
	. . . .	. . . . . .	. . . . . .
SCN	AgSCN	0.3500	34 831
	$BaSO_4$	0.4397	64 316
	. . . .	. . . . . .	. . . . . .
SO_4	$BaSO_4$	0.4116	61 445
	. . . .	. . . . . .	. . . . . .
Si	SiO_2	0.4674	66 972
	. . . .	. . . . . .	. . . . . .
Sn	SnO_2	0.7876	89 633
	. . . .	. . . . . .	. . . . . .
Sr	$SrC_2O_4 \cdot H_2O$	0.4524	65 556
	SrO	0.8456	92 716
	$SrSO_4$	0.4770	67 854
	. . . .	. . . . . .	. . . . . .
Ti	TiO_2	0.5995	77 779
	. . . .	. . . . . .	. . . . . .
Tl	Tl_2CrO_4	0.7790	89 151
	TlI	0.6169	79 024
	. . . .	. . . . . .	. . . . . .
U	U_3O_8	0.8480	92 839
	. . . .	. . . . . .	. . . . . .
W	WO_3	0.7930	89 925
	. . . .	. . . . . .	. . . . . .

Table 7 (continued)

Substance being determined	Weighed portion	Multiplier, *f*	log *f*
Zn	$Zn(C_5H_5N)_2(SCN)_2$ . . . . (pyridine)	0.1924	28 423
	$Zn(C_7H_6O_2N)_2$ . . . . . . (anthranilate)	0.1936	28 694
	$Zn(C_9H_6ON)_2$ . . . . . . (hydroxyquinolate)	0.1848	26 677
	$ZnHg(SCN)_4$	0.1312	11 790
	ZnO	0.8034	90 492
	$Zn_2P_2O_7$	0.4291	63 257
	. . . .	. . . . . .	. . . . . .
Zr	ZrO_2	0.7403	86 941
	. . . .	. . . . . .	. . . . . .

Table 8

Solubilities of Inorganic and Some Organic Compounds

The table shows the number of grams (P) of an anhydrous substance, given in the second column, which is dissolved in 100 g of water at a temperature indicated in the upper line of the table. When expressing these data in weight percentage ($P_1\%$), i.e., in grams of an anhydrous substance contained in 100 g of a saturated solution, the calculation is made by the formula $P_1 = \frac{P \cdot 100}{100+P}$.

S.Ph. stands for solid phase, i.e., a crystallohydrate which is in an equilibrium with a saturated solution. The third column gives the number of water molecules in a crystallohydrate (S.Ph.) which is in an equilibrium with a saturated solution. If the solubilities of two or more crystallohydrates of the same substance are given for the same temperature (for instance, at 0 °C the solubility of $Na_2SO_4 \cdot 10H_2O$

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
1	$AgC_2H_3O_2$ . .	—	0.72	0.88	1.04	1.21
2	AgF	$2H_2O$	—	119.8	172.0	190.1
3	$AgNO_2$ . . .	—	0.155	0.220	0.340	0.510
4	$AgNO_3$ . . .	—	122	170	222	300
5	Ag_2SO_4 . . .	—	0.57	0.69	0.79	0.88
6	$AlCl_3$	$6H_2O$	43.8	44.9	45.9	46.6
7	$Al(NO_3)_3$ . .	$9H_2O$	61	67	75.4	81
8	$Al_2(SO_4)_3$ . .	$18H_2O$	31.2	33.5	36.4	40.4
9	As_2O_3	—	1.21	—	2.04 (25 °C)	—
10	As_2O_5	—	59.5	62.1	65.9	69.5
11	B_2O_3	—	1.1	1.5	2.2	—
12	$BaBr_2$ . . .	$2H_2O$	98	101	104	109
13	$Ba(BrO_3)_2$ . .	H_2O	0.287	0.441	2.656	0.96
14	$Ba(C_2H_3O_2)_2$	$3H_2O$	59	63	71	—
15	$Ba(C_2H_3O_2)_2$	H_2O	—	—	—	75
16	$BaCl_2$	$2H_2O$	31.6	33.3	35.7	38.2
17	$Ba(ClO_3)_2$ . .	H_2O	20.33	26.95	33.80	41.70
18	$Ba(ClO_4)_2$ . .	$3H_2O$	205.8	—	289.2	—
19	BaI_2	$7{}^1/_2H_2O$	166.6	184.1	203.1	219.6
20	BaI_2	$2H_2O$	—	—	—	—

in Water

is 5.0 g per 100 g, and the solubility of $Na_2SO_4 \cdot 7H_2O$ is 19.5 g per 100 g), then the crystallohydrate having the poorest solubility will be in a *stable* equilibrium with the saturated solution, and the other crystallohydrates in a *metastable* equilibrium.

The solubility values of sparingly soluble salts are estimated by their solubility products (see Table 10).

In the table, the substances are arranged in the alphabetical order of the elements included in the formula which is written in the most common way. This must be taken into account when looking in the table for acid, base, double and complex salts whose formulas are occasionally written differently.

The solubilities of gases are given at a pressure of 760 mm Hg.

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
1.41	1.64	1.89	2.18	2.52	—	—	1
222.0	—	—	—	—	—	—	2
0.715	0.995	1.363	—	—	—	—	3
376	455	525	—	669	—	952	4
0.98	1.08	1.15	1.23	1.30	1.36	1.41	5
47.3	—	48.1	—	48.6	—	49.0	6
89	96	108	120	132.5	153	159	7
45.7	52.2	59.2	66.2	73.1	86.8	89.0	8
2.93	3.43	4.44	5.62 (75 °C)	—	—	8.17	9
71.2	—	73.0	—	75.2	—	75.7	10
4.0	—	6.2	—	9.5	—	15.7	11
114	118	123	128	135	—	149	12
1.33	1.75	2.32	3.01	3.65	4.45	5.7	13
—	—	—	—	—	—	—	14
79	77	74	74	—	—	75	15
40.7	43.6	46.4	49.4	52.4	—	58.8	16
49.61	—	66.80	—	84.84	—	104.9	17
358.7	—	426.3	—	495.2	—	562.2	18
—	—	—	—	—	—	—	19
223.7	234.3	241.3	246.6	257.1	270.4	284.5	20

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
21	$Ba(NO_2)_2$	H_2O	—	—	67.5	—
22	$Ba(NO_3)_2$	—	5.0	7.0	9.2	11.6
23	$Ba(OH)_2$	$8H_2O$	1.67	2.48	3.89	5.59
24	$BaSO_4$	—	—	2×10^{-4}	2.4×10^{-4}	2.8×10^{-4}
25	$BaSiF_6$	—	—	—	2.1×10^{-2}	2.7×10^{-2}
26	$Be(NO_3)_2$	$4H_2O$	49.4	—	—	52.3
27	$BeSO_4$	$4H_2O$	37.0	--	39.9	43.8
28	Br_2	—	4.22	3.4	3.20	3.13
29	CO	—	4.4×10^{-3}	$3.5\times$ $\times10^{-3}$	2.8×10^{-3}	2.4×10^{-3}
30	CO_2	—	0.3346	0.2318	0.1688	0.1257
31	$CaBr_2$	$6H_2O$	125	132	143	—
32	$CaBr_2$	$4H_2O$	—	—	—	—
33	$Ca(C_2H_3O_2)_2$	$2H_2O$	37.4	36.0	34.7	33.8
34	$Ca(C_2H_3O_2)_2$	H_2O	—	—	—	—
35	$CaCO_3$	—	8.1×10^{-3}	$7.0\times$ $\times10^{-3}$	6.5×10^{-3}	5.2×10^{-3}
36	$CaCl_2$	$6H_2O$	59.5	65.0	74.5	102
37	$CaCl_2$	$2H_2O$	—	—	—	—
38	$Ca(HCO_3)_2$	—	0.1615	—	0.1660	—
39	$Ca(H_2PO_2)_2$	—	—	—	15.4 (25 °C)	—
40	CaI_2	—	182.5	194.1	208.6	222.5
41	$Ca(IO_3)_2$	$6H_2O$	0.10	0.17	—	0.42
42	$Ca(IO_3)_2$	H_2O	—	—	—	—
43	$Ca(NO_2)_2$	$4H_2O$	62.1	—	76.7	—
44	$Ca(NO_2)_2$	$2H_2O$	—	—	—	—
45	$Ca(NO_3)_2$	$4H_2O$	102.1	115.3	129.3	152.6
46	$Ca(NO_3)_2$	$3H_2O$	—	—	—	—
47	$Ca(NO_3)_2$	—	—	—	—	—
48	$Ca(OH)_2$	—	0.185	0.176	0.165	0.153
49	$CaSO_3$	$2H_2O$	—	—	4.3×10^{-3}	—
50	$CaSO_4$	$2H_2O$	0.1759	0.1928	0.2036	0.209
51	$CdBr_2$	$4H_2O$	56.2	75.4	98.8	128.8
52	$CdCl_2$	$2^1/_2H_2O$	90.01	122.8	—	—
53	$CdCl_2$	H_2O	—	135.1	134.5	—
54	CdI_2	—	79.8	83.2	86.2	89.7

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
101.2	—	141.9	—	205.8	—	300	21
14.2	17.1	20.3	23.6	27.0	30.6	34.2	22
8.22	13.12	20.94	35.6	101.4	—	—	23
—	—	—	—	4×10^{-4}	—	—	24
3×10^{-2}	3.3×10^{-2}	—	—	—	—	9×10^{-2}	25
—	58.6	64.0	—	—	—	—	26
46.7	—	55.5	62	—	83	100	27
—	—	—	—	—	—	—	28
2.1×10^{-3}	1.8×10^{-3}	1.5×10^{-3}	1.3×10^{-3}	1.0×10^{-3}	6×10^{-4}	—	29
0.0973	0.0761	0.0576	—	—	—	—	30
—	—	—	—	—	—	—	31
68.1	—	73.5	—	74.7	—	—	32
33.2	32.8	32.7	33.0	33.5	—	—	33
—	—	—	—	—	31.1	29.7	34
4.4×10^{-3}	3.8×10^{-3}	—	—	—	—	—	35
—	—	—	—	—	—	—	36
—	—	136.8	141.7	147.0	152.7	159.0	37
0.1705	—	0.1750	—	0.1795	—	0.1840	38
—	—	—	—	—	—	12.5	39
242.4	—	284.5	—	354.6	—	426.3	40
0.61	0.90	1.38	—	—	—	—	41
0.52	0.59	0.65	—	0.80	—	0.95	42
—	—	—	—	—	—	—	43
—	—	132.5	151.9	—	244.8	—	44
196.0	—	—	—	—	—	—	45
237.5	281.5	—	—	—	—	—	46
—	—	—	—	358.7	—	363.7	47
0.141	0.128	0.116	0.106	0.094	0.085	0.077	48
6.3×10^{-3}	—	—	4.5×10^{-3}	3.1×10^{-3}	2.7×10^{-3}	1.1×10^{-3}	49
0.2097	—	0.2047	0.1974	0.1966	—	0.1619	50
151.9	—	152.9	—	155.1	—	160.8	51
—	—	—	—	—	—	—	52
135.3	—	136.5	—	140.5	—	147.0	53
93.8	97.4	100.4	110.0	—	—	124.9	54

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
55	$Cd(NO_3)_2$	$9H_2O$	106	—	—	—
56	$Cd(NO_3)_2$	$4H_2O$	—	—	153	—
57	$Cd(NO_3)_2$	—	—	—	—	—
58	$CdSO_4$	$^8/_3H_2O$	75.4	76.1	—	77.7
59	$CdSO_4$	H_2O	—	—	—	—
60	$Ce(NH_4)_2(NO_3)_6$	—	—	—	129.3	153.8
61	$CeNH_4(SO_4)_2$	$4H_2O$	—	—	5.33	—
62	$Ce_2(SO_4)_3$	$9H_2O$	20.98	—	10.08	6.79
63	$Ce_2(SO_4)_3$	$8H_2O$	16.96	—	9.52	—
64	$Ce_2(SO_4)_3$	$5H_2O$	—	—	—	—
65	$Ce_2(SO_4)_3$	$4H_2O$	—	—	—	—
66	Cl_2	—	1.46	0.980	0.716	0.562
67	$CoCl_2$	$6H_2O$	43.5	47.7	52.9	59.7
68	$CoCl_2$	$2H_2O$	—	—	—	—
69	CoI_2	$6H_2O$	138.1	159.7	187.4	233.3
70	$Co(IO_3)_2$	$2H_2O$	—	—	0.45	0.52
71	$Co(NO_3)_2$	$6H_2O$	84.05	—	100.0	111.4
72	$Co(NO_3)_2$	$3H_2O$	—	—	—	—
73	$Co(NO_2)_2$	—	0.076	0.24	0.40	0.60
74	$CoSO_4$	$7H_2O$	25.5	—	36.3	—
75	$CoSO_4$	$6H_2O$	—	—	—	—
76	$CoSO_4$	H_2O	—	—	—	—
77	CrO_3	—	164.8	166.0	167.4	169.5
78	$CsAl(SO_4)_2$	$12H_2O$	0.34	—	0.46	—
79	$CsCl$	—	161.4	174.7	186.5	197.3
80	$CsClO_3$	—	2.46	3.8	6.2	9.5
81	$CsClO_4$	—	0.8	1.0	1.6	2.6
82	CsF	$1^1/_2H_2O$	—	—	366.6 (18 °C)	—
83	$CsIO_3$	—	—	—	2.6 (24 °C)	—
84	$CsIO_4$	—	—	2.15 (15 °C)	—	—
85	$CsNO_3$	—	9.33	14.9	23.0	33.9
86	$CsOH$	—	—	79.41 (15 °C)	—	75.18

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
—	—	—	—	—	—	—	55
199	—	—	—	—	—	—	56
—	—	619	—	646	—	682	57
78.6	—	—	—	—	—	—	58
—	77.1	—	70.3	67.6	64.5	58.4	59
183.0	—	196.5	—	219.6	—	—	60
3.29	—	—	—	—	1.05	—	61
—	4.67	3.88	—	—	—	—	62
5.95	—	4.04	—	—	—	—	63
—	—	3.25	—	1.20	—	0.46	64
6.05	3.42	2.35	—	1.01	—	0.41	65
0.451	0.386	0.324	0.274	0.219	0.125	0	66
69.5	—	—	—	—	—	—	67
—	88.7	93.8	95.3	97.6	101.2	106.2	68
300.0	376.1	—	—	400.0	—	—	69
—	0.67	—	—	—	—	1.33	70
126.8	—	—	—	—	—	—	71
—	—	167.4	184.8	220.5	334.8	—	72
0.84	—	—	—	—	—	—	73
49.9	—	—	—	—	—	—	74
—	—	55.0	—	—	—	—	75
—	—	—	—	73.8	—	83.9	76
174.0	182.5	186.5	—	194.1	198.6	206.7	77
0.89	—	2.00	—	5.49	—	42.54	78
208.0	218.3	229.7	239.5	250.0	260.1	270.5	79
13.8	19.4	26.2	34.7	45.0	58.0	79.0	80
4.0	5.4	7.3	9.8	14.4	20.5	30.0	81
—	—	160	—	—	—	—	82
—	—	—	—	—	—	—	83
—	—	—	—	—	—	—	84
47.2	64.4	83.8	107.0	134.0	163.0	197.0	85
—	—	—	—	—	—	—	86

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
87	Cs_2PtCl_6	—	4.7×10^{-3}	$6.4\times\times10^{-3}$	8.6×10^{-3}	$11.9\times\times10^{-3}$
88	Cs_2SO_4	—	167.1	173.1	178.7	184.1
89	$CuBr_2$	$4H_2O$	107.5	116.0	126.8	127.7
90	$CuCl_2$	$4H_2O$	68.6	70.9	—	—
91	$CuCl_2$	$2H_2O$	—	—	72.7	77.3
92	CuI_2	—	—	—	1.107	—
93	$Cu(IO_3)_2$	H_2O	—	—	0.153	—
94	$Cu(NH_4)_2Cl_4$	$2H_2O$	28.24	—	35.05	—
95	$Cu(NO_3)_2$	$6H_2O$	81.8	100.0	124.8	154.4
96	$Cu(NO_3)_2$	$3H_2O$	—	—	—	—
97	$CuSO_4$	$5H_2O$	14.3	17.4	20.7	25.0
98	$FeBr_2$	$6H_2O$	102.1	—	115.0	122.3
99	$FeCl_2$	$4H_2O$	—	64.5	—	73.0
100	$FeCl_2$	$2H_2O$	—	—	—	—
101	$FeCl_3$	$6H_2O$	74.4	81.8	91.9	106.8
102	$FeCl_3$	$2H_2O$	—	—	—	—
103	$FeCl_3$	—	—	—	—	—
104	$Fe(NO_3)_3$	$6H_2O$	78.03	—	83.03	—
105	$FeSO_4$	$7H_2O$	15.65	20.5	26.5	32.9
106	$FeSO_4$	H_2O	—	—	—	—
107	H_2	—	$1.982\times\times10^{-4}$	$1.740\times\times10^{-4}$	$1.603\times\times10^{-4}$	$1.474\times\times10^{-4}$
108	H_3BO_3	—	2.66	3.57	5.04	6.72
109	HBr	—	221.2	210.3	198.2	—
110	$H_2C_2O_4$	$2H_2O$	3.54	6.08	9.52	14.3
111	$H_2C_4H_4O_4$ (succinic)	—	2.80	4.50	6.91	10.62
112	$H_2C_4H_4O_6$ (tartaric)	—	115.0	126.3	139.2	156.4
113	$H_3C_6H_5O_7$ (citric)	H_2O	96	118	146	183
114	$H_3C_6H_5O_7$	—	—	—	—	—
115	$HC_7H_5O_2$ (benzoic)	—	0.17	0.21	0.29	0.41
116	$HC_7H_5O_3$ (salycylic)	—	0.090	0.14	0.22	0.30
117	HCl	—	82.3	—	—	67.3
118	HIO_3	—	236.7	—	257.1	—

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
15.8×10^{-3}	21.2×10^{-3}	29.0×10^{-3}	38.9×10^{-3}	52.5×10^{-3}	67.5×10^{-3}	91.5×10^{-3}	87
189.9	194.9	199.9	205.0	210.3	214.9	220.3	88
—	131.4	—	—	—	—	—	89
—	—	—	—	—	—	—	90
80.8	84.2	87.6	92.3	96.1	103.6	110.0	91
—	—	—	—	—	—	—	92
—	—	—	—	—	—	0.65	93
43.82	—	56.57	—	76.56	—	—	94
—	—	—	—	—	—	—	95
163.1	171.8	181.8	194.1	207.8	222.5	247.3	96
28.5	33.3	40.0	47.1	55	64.2	75.4	97
128.3	—	143.9	—	159.7	—	177.8	98
77.3	82.5	88.7	—	100.0	—	—	99
—	—	—	—	—	105.3	105.8	100
—	—	—	—	—	—	—	101
—	315.2	—	—	—	—	—	102
—	—	—	—	525.0	—	536.9	103
—	—	166.6	—	—	—	—	104
40.2	48.6	—	—	—	—	—	105
—	—	—	50.9	43.6	37.3	—	106
1.384×10^{-4}	1.287×10^{-4}	1.178×10^{-4}	1.021×10^{-4}	0.790×10^{-4}	0.461×10^{-4}	0	107
8.72	11.54	14.81	18.62	23.62	30.38	40.3	108
—	171.3	—	—	—	—	130.0	109
21.5	31.4	44.3	65.0	84.5	119.8	—	110
16.1	24.4	35.9	51.1	70.9	—	121.3	111
176.2	195.0	218.5	244.8	273.2	—	344.4	112
—	—	—	—	—	—	—	113
216	244	278	—	371	—	526	114
0.56	0.78	1.16	—	2.71	—	5.88	115
0.42	0.64	0.90	1.39	2.26	3.89	8.12	116
63.3	59.6	56.1	—	—	—	—	117
280.2	—	314.9	—	360.8	—	420.8	118

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
119	H_2S	—	0.699	0.502	0.378	0.294
120	H_2SeO_3	—	90.1	122.3	166.6	235.6
121	H_2SeO_4	H_2O	426.3	—	566.6	—
122	H_2SeO_4	—	—	—	—	132.5
123	H_2TeO_4	$6H_2O$	16.17	35.52	—	—
124	H_2TeO_4	$2H_2O$	—	33.85	—	50.05
125	$HgBr_2$	—	0.3	0.4	0.55	0.65
126	$Hg(CN)_2$	—	—	9.3 (13.5 °C)	—	—
127	$HgCl_2$	—	4.3	5.6	6.6	8.3
128	Hg_2Cl_2	—	1.4×10^{-4}	—	2×10^{-4}	7×10^{-4}
129	I_2	—	$1.62 \times$ $\times 10^{-2}$	$1.9 \times$ $\times 10^{-2}$	2.9×10^{-2}	4.0×10^{-2}
130	$KAl(SO_4)_2$	$12H_2O$	3.0	4.0	5.9	8.4
131	$KAuBr_4$	$2H_2O$	—	18.3 (15 °C)	—	—
132	$KAuCl_4$	$2H_2O$	—	38.3	61.8	94.9
133	$KBeF_3$	—	—	—	2.0	—
134	KBr	—	53.5	59.5	65.5	70.6
135	$KBrO_3$	—	3.1	4.8	6.9	9.5
136	$KC_2H_3O_2$	$1^1/_2H_2O$	216.7	233.9	255.6	283.8
137	$KC_2H_3O_2$	$^1/_2H_2O$	—	—	—	—
138	KCN	—	63	—	71.6 (25 °C)	—
139	K_2CO_3	$1^1/_2H_2O$	105.3	108.3	110.5	113.7
140	$K_2C_2O_4$	H_2O	20.3	23.7	26.4	28.6
141	KCl	—	27.6	31.0	34.0	37.0
142	$KClO_3$	—	3.3	5.0	7.4	10.5
143	$KClO_4$	—	0.75	1.05	1.80	2.6
144	K_2CrO_4	—	58.2	60.0	61.7	63.4
145	$K_2Cr_2O_7$	—	5.0	8.5	13.1	18.2
146	$KCr(SO_4)_2$	$12H_2O$	—	—	12.51 (25 °C)	—
147	KF	$4H_2O$	44.72	53.55	—	—
148	KF	$2H_2O$	—	—	94.93	108.1
149	KF	—	—	—	—	—
150	$K_3Fe(CN)_6$	—	~30	36.6	42.9	—
151	$K_4Fe(CN)_6$	$3H_2O$	14.9	21.2	28.9	36.8
152	$KHCO_3$	—	22.6	27.7	33.3	39.1

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
0.232	0.186	0.146	0.109	0.076	0.041	0.000	119
344.4	380.7	383.0	383.0	383.0	385.4	—	120
—	—	—	—	—	—	—	121
1718	2753	∞	—	—	—	—	122
—	—	—	—	—	—	—	123
57.19	—	77.54	—	106.4	—	155.3	124
0.91	1.27	1.68	—	2.8	—	4.9	125
—	—	—	—	—	—	53.85	126
9.9	11.1	14.9	17.2	24.2	37.2	63.6	127
—	—	—	—	—	—	—	128
5.6×10^{-2}	7.8×10^{-2}	10.6×10^{-2}	—	—	—	—	129
11.7	17.0	24.8	40.0	71.0	109.0	154	130
—	—	—	—	—	—	192	131
145	233	405	—	—	—	—	132
—	—	—	—	—	—	5.2	133
75.5	80.2	85.1	90.0	95.0	99.2	104.0	134
13.2	17.5	22.7	—	34.0	—	50.0	135
323.3	—	—	—	—	—	—	136
—	337.3	350.0	364.8	380.1	396.3	—	137
—	81	—	—	95	—	122	138
116.9	121.3	126.8	133.5	139.8	147.5	155.7	139
30.8	33.0	35.1	37.2	39.5	41.3	44.0	140
40.0	42.6	45.5	48.1	51.1	54.0	56.7	141
14.0	19.3	25.9	32.5	39.7	47.7	56.2	142
4.4	6.5	9.0	11.8	14.8	18.0	21.8	143
65.2	66.8	68.6	70.4	72.1	73.9	75.6	144
29.2	37.0	50.5	61.5	73.0	96.2	102.0	145
—	—	—	—	—	—	—	146
—	—	—	—	—	—	—	147
—	—	—	—	—	—	—	148
—	—	142.2	—	150.1	—	—	149
61.3	—	71.0	—	81.8	—	91.6	150
42.7	—	55.9	57.5	68.6	74.8	77.8	151
45.3	52.0	60.0	—	—	—	—	152

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
153	$KH_3(C_2O_4)_2$	$2H_2O$	1.27	—	—	4.29
154	$KHC_4H_4O_6$	—	0.32	0.40	0.53	0.90
155	$KHC_8H_4O_4$ (hydrophthalate)	—	—	—	10	—
156	KHF_2	—	24.53	30.10	39.18	—
157	KH_2PO_4	—	14.8	18.4	22.6	—
158	$KHSO_4$	—	36.3	—	51.4	—
159	KI	—	127.5	136	144	152
160	KIO_3	—	4.73	—	8.13	11.73
161	KIO_4	—	0.17	—	0.42	—
162	$KMnO_4$	—	2.83	4.4	6.4	9.0
163	KNO_2	—	278.8	—	298.4	—
164	KNO_3	—	13.3	20.9	31.6	45.8
165	$KNaC_4H_4O_6$	$4H_2O$	28.4	40.6	54.8	76.4
166	KOH	$2H_2O$	97	103	112	126
167	KOH	H_2O	—	—	—	—
168	K_2PtCl_6	—	0.74	0.90	1.12	1.41
169	$KSCN$	—	177	196	217.5	255
170	K_2SO_3	—	106.2	106.6	106.0	—
171	K_2SO_4	—	7.35	9.22	11.11	12.97
172	$K_2S_2O_5$	—	28.4	36.2	44.7	—
173	$K_2S_2O_8$	—	1.8	2.7	4.7	7.7
174	$KSbOC_4H_4O_6$	$^{1}/_{2}H_2O$	—	5.3	8.0	12.2
175	K_2SiF_6	—	—	—	0.12	—
176	$La_2(SO_4)_3$	$9H_2O$	3.0	—	—	1.9
177	$LiBr$	$2H_2O$	143	166	177	191
178	$LiBr$	H_2O	—	—	—	—
179	Li_2CO_3	—	1.54	1.43	1.33	1.25
180	$LiCl$	H_2O	67	72	78.5	84.5
181	LiF	—	—	—	0.26 (18 °C)	—
182	LiI	$3H_2O$	151	157	165	171
183	LiI	H_2O	—	—	—	—
184	$LiNO_3$	$3H_2O$	53.4	61.0	74.5	132.5
185	$LiNO_3$	$^{1}/_{2}H_2O$	—	—	—	—
186	$LiNO_3$	—	—	—	—	—
187	$LiOH$	H_2O	12.7	12.7	12.8	12.9
188	Li_2SO_4	H_2O	35.3	35.0	34.2	33.5

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
—	—	12.0	—	—	—	66.7	153
1.3	1.8	2.5	—	4.6	—	7.0	154
—	—	—	—	—	—	33	155
							156
56.37	—	78.83	—	114.0	—	—	157
33.5	—	50.1	—	70.4	83.5	—	158
67.3	—	—	—	—	—	121.6	159
160	168	176	184	192	200	208	160
12.8	—	18.5	—	24.8	—	32.2	161
0.93	—	2.16	—	4.44	—	7.87	162
12.56	16.89	22.2	—	—	—	—	163
334.8	—	350	—	376	—	412.9	164
63.9	85.5	110.0	138	169	202	240	165
—	—	—	—	-	—	—	166
—	—	—	—	—	—	—	167
136	140	147	—	160	—	178	168
1.76	2.17	2.64	3.19	3.79	4.45	5.18	169
290	325	372	420	488	575	674	170
108.7	—	—	—	111.4	122.3	—	171
14.76	16.56	18.17	19.75	21.4	22.4	24.1	172
64.0	—	83.2	—	106.6	119.3	—	173
11.0	—	—	—	—	—	—	174
— 0.25	— —	— —	31.2 (75 °C) —	— 0.46	— —	35.9 0.954	175
—	1.5	—	—	—	—	0.69	176
205	—	—	—	—	—	—	177
—	214	224	—	245	—	226	178
1.17	1.08	1.01	—	0.85	—	0.72	179
90.5	97	103	—	115	—	127.5	180
—	—	—	—	—	—	—	181
179	187	202	230	—	—	—	182
—	—	—	—	435	—	481	183
—	—	—	—	—	—	—	184
145.1	156.4	174.8	—	—	—	—	185
—	—	—	194.1	—	—	—	186
13	13.3	13.8	—	15.3	—	17.5	187
32.8	32.5	31.9	—	30.7	—	29.9	188

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
189	$MgBr_2$ . . .	$6H_2O$	91.0	94.5	96.5	99.2
190	$MgCl_2$	$6H_2O$	52.8	53.5	54.5	—
191	MgI_2	$8H_2O$	120.8	—	139.8	—
192	$MgNH_4AsO_4$	$6H_2O$	—	—	3.8×10^{-2}	—
193	$MgNH_4PO_4$	$6H_2O$	2.3×10^{-2}	—	5.2×10^{-2}	—
194	$Mg(NO_3)_2$ . .	$6H_2O$	62.6	—	70.1	74.8
195	$MgSO_4$ . . .	$7H_2O$	—	30.9	35.5	40.8
196	$MgSO_4$ . . .	$6H_2O$	40.8	42.3	44.5	45.4
197	$MgSO_4$ . . .	H_2O	—	—	—	—
198	$MnBr_2$ . . .	$4H_2O$	127.3	135.8	146.9	157.0
199	$MnBr_2$ . . .	$2H_2O$	—	—	—	—
200	$MnCl_2$ . . .	$4H_2O$	63.4	68.1	73.9	80.7
201	$MnCl_2$	$2H_2O$	—	—	—	—
202	$Mn(H_2BO_3)_2$	H_2O	—	0.19 (14 °C)	—	—
203	$Mn(NO_3)_2$ . .	$6H_2O$	102.0	117.9	142.8	—
204	$Mn(NO_3)_2$ . .	$3H_2O$	—	—	—	206.5
205	$MnSO_4$ . . .	$7H_2O$	53.23	60.01	—	—
206	$MnSO_4$ . . .	$5H_2O$	—	59.5	62.9	67.76
207	$MnSO_4$ . . .	$4H_2O$	—	—	64.5	66.4
208	$MnSO_4$ . . .	H_2O	—	—	—	—
209	MoO_3 . . .	—	—	—	0.138	0.264
210	NH_3	—	89.7	68.3	52.9	40.9
211	$NH_4Al(SO_4)_2$	$12H_2O$	2.72	4.81	7.17	10.10
212	NH_4Br . . .	—	60.6	68	75.5	83.2
213	$(NH_4)_2C_2O_4$	H_2O	2.4	3.2	4.5	6.0
214	NH_4Cl . . .	—	29.4	33.3	37.2	41.4
215	NH_4ClO_4** .	—	11.56	—	20.85	—
216	$(NH_4)_2Co(SO_4)_2$	$6H_2O$	6.0	9.5	13.0	17.0
217	$(NH_4)_2CrO_4$	—	25.01	—	32.96	40.4
218	$(NH_4)_2Cr_2O_7$	—	18.26	—	35.6	46.5
219	$NH_4Cr(SO_4)_2$ (violet)	$12H_2O$	3.9	—	—	11.9

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* S. Ph. with $6H_2O$.

** For NH_4ClO_4, solubility is expressed in g of anhydrous NH_4ClO_4 contained

Table 8 (continued)

ture, °C							
40	50	60	70	80	90	100	No.
100 g of water at a given temperature, g							
101.6	104.1	107.5	—	113.7	—	120.2	189
57.5	—	61.0	—	66.0	—	73.0	190
173.2	—	—	—	185.7*	—	—	191
—	—	—	—	2.4×10^{-2}	—	—	192
4×10^{-2}	—	4×10^{-2}	—	1.9×10^{-2}	—	—	193
78.9	84.5	91.2	—	106.2	138.1	—	194
45.6	—	—	—	—	—	—	195
—	50.4	55.0	59.5	64.2	68.9	73.9	196
—	—	—	—	62.9	—	68.3	197
168.9	181.8	196.7	212.5	—	—	—	198
—	—	—	—	224.7	225.7	227.9	199
88.6	98.2	—	—	—	—	—	200
—	—	108.6	110.6	112.7	114.1	115.3	201
—	0.69	—	—	—	—	—	202
—	—	—	—	—	—	—	203
—	—	—	—	—	—	—	204
—	—	—	—	—	—	—	205
—	—	—	—	—	—	—	206
68.8	72.6	—	—	—	—	—	207
—	58.2	55.0	52.0	48.0	42.5	34.0	208
0.476	0.687	1.206	2.055	2.106	—	—	209
31.6	23.5	16.8	11.1	6.5	3.0	0.0	210
14.29	19.1	26.8	37.7	53.9	98.2	120.7	211
91.1	99.2	107.8	116.8	126.0	135.6	145.6	212
8.2	10.7	—	—	—	—	—	213
45.8	50.4	55.2	60.2	65.6	71.3	77.3	214
30.58	—	39.05	—	48.19	—	57.01	215
22.0	27.0	33.5	40.0	49.0	—	—	216
—	51.87	—	81.83 (75 °C)	—	—	—	217
58.5	71.4	86.0	—	115.0	—	155.6	218
18.3	—	—	—	—	—	—	219

in 100 ml of a saturated solution.

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
220	$NH_4Cr(SO_4)_2$ (green)	$12H_2O$	3.9	—	—	19.0
221	NH_4F . . .	—	50	74	—	—
222	$(NH_4)_2Fe(SO_4)_2$	$6H_2O$	17.8	—	26.9	—
223	$NH_4Fe(SO_4)_2$	$12H_2O$	—	—	124	—
224	NH_4HCO_3 . .	—	11.9	15.8	21	27
225	$NH_4H_2PO_3$	—	171	190 (14.5 °C)	—	260
226	$NH_4H_2PO_4$ . .	—	22.7	—	36.8	—
227	$(NH_4)_2HPO_4$	—	42.9	57.5	68.6	—
228	NH_4I	—	154.2	163.2	172.3	181.4
229	NH_4LiSO_4	—	—	55.24	—	55.94
230	NH_4NO_3 . .	—	118.3	—	192.0	241.8
231	$(NH_4)_2PtCl_6$	—	—	0.7	—	—
232	NH_4SCN . .	—	119.8	143.9	170.2	207.7
233	$(NH_4)_2SO_4$	—	70.6	73.0	75.4	78.0
234	$(NH_4)_2S_2O_8$	—	58.2	—	—	—
235	$(NH_4)_3SbS_4$	$4H_2O$	71.2	—	91.2	119.8
236	$(NH_4)_2SeO_4$	—	—	1.22 (12 °C)	—	—
237	$(NH_4)_2SiF_6$	—	—	—	18.6	—
238	NH_4VO_3 . .	—	—	—	4.8	8.4
239	NO	—	9.84×10^{-3}	7.57×10^{-3}	6.18×10^{-3}	5.17×10^{-3}
240	N_2O	—	—	0.171	0.121	—
241	$Na_2B_4O_7$ . .	$10H_2O$	1.3	1.6	2.7	3.9
242	$Na_2B_4O_7$ . .	$5H_2O$	—	—	—	—
243	$NaBeF_3$ . . .	—	—	—	1.4	—
244	NaBr	$2H_2O$	79.5	—	90.5	97.6
245	NaBr	—	—	—	—	—
246	$NaBrO_3$ . . .	—	27.5	—	34.5	—
247	$NaC_2H_3O_2$ . .	$3H_2O$	36.3	40.8	46.5	54.5
248	$NaC_2H_3O_2$ . .	—	—	—	—	126
249	Na_2CO_3 . . .	$10H_2O$	7	12.5	21.5	38.8
250	Na_2CO_3 . . .	H_2O	—	—	—	50.5
251	$Na_2C_2O_4$ . .	—	—	—	3.7	—
252	NaCl	—	35.7	35.8	36.0	36.3
253	NaClO . . .	—	29.4	36.4	53.4	100.0
254	$NaClO_3$ . . .	—	79	89	101	113
255	$NaClO_4$ . . .	H_2O	167	—	181	—
256	$NaClO_4$ . . .	—	—	—	—	—

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
32.8	—	—	—	—	—	—	220
—	—	111	—	—	—	—	221
38.5	—	53.4	—	73.0	—	—	222
—	—	—	—	—	—	400	223
36.6	—	—	—	—	—	—	224
—	—	—	—	—	—	—	225
56.7	—	82.9	—	120.7	—	174	226
81.8	—	97.6	106.0	—	—	—	227
190.5	199.6	208.9	218.7	228.8	—	250.3	228
—	56.24	—	56.70	—	—	—	229
297.0	344.0	421.0	499.0	580.0	740.0	871.0	230
—	—	—	—	—	—	1.25	231
—	235	—	347	—	—	—	232
81.0	—	88.0	—	95.3	—	103.3	233
—	—	—	—	—	—	—	234
—	—	—	—	—	—	—	235
—	—	—	—	—	—	—	236
—	—	—	—	—	—	55.5	237
13.2	17.8	—	30.5	—	—	—	238
4.40 × × 10^{-3}	3.76 × × 10^{-3}	3.24 × × 10^{-3}	2.67 × × 10^{-3}	1.99 × × 10^{-3}	1.14 × × 10^{-3}	0	239
—	—	—	—	—	—	—	240
6.7	10.5	20.3	—	—	—	—	241
—	—	—	24.4	31.5	41.0	52.5	242
—	—	—	—	—	—	2.8	243
105.8	116.0	—	—	—	—	—	244
—	—	—	—	118.3	—	121.3	245
50.2	—	62.5	—	75.7	—	90.9	246
65.5	83	139	—	—	—	—	247
129.5	134	139.5	146	153	161	170	248
—	—	—	—	—	—	—	249
48.5	—	46.4	46.2	45.8	45.7	45.5	250
—	—	—	—	—	—	6.33	251
36.6	37.0	37.3	37.8	38.4	39.0	39.8	252
110.5	129.9	—	—	—	—	—	253
126	140	155	172	189	—	230	254
243	—	—	—	—	—	—	255
—	—	289	—	304	—	324	256

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
257	Na_2CrO_4	$10H_2O$	31.70	50.17	88.7	—
258	Na_2CrO_4	$4H_2O$	—	—	—	88.7
259	Na_2CrO_4	—	—	—	—	—
260	$Na_2Cr_2O_7$	$2H_2O$	163.0	170.2	180.1	196.7
261	$Na_2C_2O_7$	—	—	—	—	—
262	NaF	—	3.53	4.01 (15 °C)	4.17	4.20
263	$Na_4Fe(CN)_6$	$10H_2O$	—	—	17.9	—
264	Na_2HAsO_4	$12H_2O$	5.9	16.4	33.9	49.3
265	$NaHCO_3$	—	6.9	8.15	9.6	11.1
266	NaH_2PO_4	$2H_2O$	57.9	69.9	85.2	106.5
267	NaH_2PO_4	H_2O	—	—	—	—
268	NaH_2PO_4	—	—	—	—	—
269	Na_2HPO_4	$12H_2O$	1.67	3.6	7.7	20.8
270	Na_2HPO_4	$7H_2O$	—	—	—	—
271	Na_2HPO_4	$2H_2O$	—	—	—	—
272	Na_2HPO_4	—	—	—	—	—
273	NaI	$2H_2O$	158.7	168.6	178.7	190.3
274	NaI	—	—	—	—	—
275	$NaIO_3$	H_2O	2.5	4.6	9.0	11.0
276	$NaIO_3$	—	—	—	—	—
277	Na_2MoO_4	$10H_2O$	44.3	64.7	—	—
278	Na_2MoO_4	$2H_2O$	—	—	65.0	66.1
279	$NaNO_2$	—	72.1	77.9	84.5	91.6
280	$NaNO_3$	—	73	80	88	96
281	NaOH	$4H_2O$	42	51	—	—
282	NaOH	H_2O	—	—	109	119
283	NaOH	—	—	—	—	—
284	Na_3PO_4	$12H_2O$	1.5	4.1	11	20
285	$Na_4P_2O_7$	$10H_2O$	3.16	3.95	6.23	9.95
286	Na_2S	$9H_2O$	—	15.42	18.8	22.6
287	Na_2S	$6H_2O$	—	—	—	—
288	Na_2SO_3	$7H_2O$	13.9	20	26.9	36
289	Na_2SO_3	—	—	—	—	—
290	Na_2SO_4	$10H_2O$	5.0	9.0	19.4	40.8
291	Na_2SO_4	$7H_2O$	19.5	30	44	—
292	Na_2SO_4	—	—	—	—	50.4
293	$Na_2S_2O_3$	$5H_2O$	52.5	61.0	70.0	84.7
294	$Na_2S_2O_3$	$2H_2O$	—	—	—	—
295	$Na_2S_2O_3$	—	—	—	—	—
296	$Na_2S_2O_5$	$7H_2O$	45.5	—	—	—
297	$Na_2S_2O_5$	—	—	—	65.3	—
298	Na_2SeO_4	$10H_2O$	13.30	—	—	78.74

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
—	—	—	—	—	—	—	257
95.94	104.1	114.6	—	—	—	—	258
—	—	—	123.1	124.8	—	126.2	259
220.5	248.4	283.1	323.8	385.4	—	—	260
—	—	—	—	—	—	431.9	261
4.40	4.55	4.68	—	4.89	—	5.08	262
30	—	—	—	59	—	63	263
69.5	99.4	144	184	186	189	198	264
12.7	14.45	16.4		Decomposes			265
138.2	—	—	—	—	—	—	266
—	158.6	—	—	—	—	—	267
—	—	179.3	190.3	207.3	225.3	246.6	268
—	—	—	—	—	—	—	269
51.8	—	—	—	—	—	—	270
—	80.2	82.9	88.1	92.4	102.9	—	271
—	—	—	—	—	—	102.2	272
205.0	227.8	256.8	—	—	—	—	273
—	—	—	294	296	300	302	274
13.3	16.3	19.8	23.5	—	—	—	275
—	—	—	—	28.5	29.5	33.0	276
—	—	—	—	—	—	—	277
—	70.7	—	—	—	—	83.8	278
98.4	104.1	—	—	132.5	—	163.1	279
104	114	124	—	148	—	180	280
—	—	—	—	—	—	—	281
129	145	174	—	—	—	—	282
—	—	—	299	313.7	—	347	283
31	43	55	—	81	—	108	284
13.50	17.45	21.83	—	30.04	—	40.26	285
28.5	—	—	—	—	—	—	286
—	36.4	39.1	43.31	49.15	57.28	—	287
—	—	—	—	—	—	—	288
37.0	—	33.2	—	29.0	—	26.6	289
—	—	—	—	—	—	—	290
—	—	—	—	—	—	—	291
48.8	46.7	45.3	44.1	43.7	42.9	42.5	292
102.6	—	—	—	—	—	—	293
—	—	206.6	—	—	—	—	294
—	—	—	—	245	—	266	295
—	—	—	—	—	—	—	296
71.1	—	79.9	—	88.7	—	100	297
—	—	—	—	—	—	—	298

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
299	Na_2SeO_4 . .	—	—	—	—	—
300	Na_2SiF_6 . . .	—	0.43	—	0.73	—
301	$NaVO_3$ . . .	—	—	—	—	—
302	Na_2WO_4 . .	$10H_2O$	57.58	—	—	—
303	Na_2WO_4 . .	$2H_2O$	71.61	—	72.4	—
304	$Nd_2(SO_4)_3$ . .	$8H_2O$	9.6	—	7.1	5.3
305	$NiBr_2$	$3H_2O$	112.8	122.3	130.9	138.1
306	$NiCl_2$	$6H_2O$	51.7	—	55.3	—
307	$NiCl_2$	$4H_2O$	—	—	—	—
308	$NiCl_2$	$2H_2O$	—	—	—	—
309	NiI_2	—	124.3	135.3	148.1	161.1
310	$Ni(NH_4)_2(SO_4)_2$	$6H_2O$	—	3.2	5.9	7.8
311	$Ni(NO_3)_2$ . .	$6H_2O$	79.58	—	96.32	—
312	$Ni(NO_3)_2$ . .	$4H_2O$	—	—	—	—
313	$Ni(NO_3)_2$ . .	$2H_2O$	—	—	—	—
314	$NiSO_4$ . . .	$7H_2O$	27.22	32	—	42.46
315	$NiSO_4$ . . .	$6H_2O$	—	—	—	—
316	O_2	—	$6.948 \times$ $\times 10^{-3}$	$5.370 \times$ $\times 10^{-3}$	$4.339 \times$ $\times 10^{-3}$	$3.508 \times$ $\times 10^{-3}$
317	O_3	—	$3.9 \times$ $\times 10^{-3}$	$2.9 \times$ $\times 10^{-3}$	$2.1 \times$ $\times 10^{-3}$	7×10^{-4}
318	$PbBr_2$ . . .	—	0.4554	—	0.85	1.15
319	$Pb(C_2H_3O_2)_2$	$3H_2O$	—	45.6 (15 °C)	55.0 (25 °C)	—
320	$PbCl_2$	—	0.6728	—	0.99	1.20
321	$PbCrO_4$ . . .	—	—	—	$4.3 \times$ $\times 10^{-6}$	—
322	PbI_2	—	$4.42 \times$ $\times 10^{-2}$	—	$6.8 \times$ $\times 10^{-2}$	$9.0 \times$ $\times 10^{-2}$
323	$Pb(NO_3)_2$ . .	—	38.8	48.3	56.5	66
324	$PbSO_4$ . . .	—	$2.8 \times$ $\times 10^{-3}$	$3.5 \times$ $\times 10^{-3}$	$4.1 \times$ $\times 10^{-3}$	$4.9 \times$ $\times 10^{-3}$
325	$RbAl(SO_4)_2$	$12H_2O$	0.72	—	2.59	—
326	$RbCl$	—	77.0	84.4	91.1	97.6
327	$RbClO_3$ . . .	—	2.14	—	5.4	8.0
328	$RbClO_4$ . . .	—	0.5	0.6	1.0	1.5
329	$RbNO_3$ . . .	—	19.5	33.0	53.3	81.3

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
—	80.15	—	—	—	—	72.83	299
1.03	—	—	—	1.86	—	2.46	300
26.23	—	32.97	36.9	—	—	—	301
—	—	—	—	—	—	—	302
77.9	—	—	—	91.2	—	97.2	303
4.1	3.3	2.8	2.5	—	1.2	1.2	304
144.5	150.0	152.5	—	153.8	—	155.1	305
—	—	—	—	—	—	—	306
72.5	—	80.5	—	—	—	—	307
—	—	—	—	86.9	—	88.0	308
174.0	183.2	184.1	185.7	187.4	188.2	—	309
11.5	14.4	17.0	19.8	25.5	—	—	310
122.3	—	—	—	—	—	—	311
—	—	163.1	177.4	—	—	—	312
—	—	—	—	—	235.2	—	313
—	—	—	—	—	—	—	314
—	50.15	54.80	59.44	63.17	—	76.7	315
3.081×10^{-3}	2.657×10^{-3}	2.274×10^{-3}	1.857×10^{-3}	1.381×10^{-3}	7.87×10^{-4}	0	316
4×10^{-4}	1×10^{-4}	0	—	—	—	—	317
1.53	1.94	2.36	—	3.34	—	4.75	318
—	—	—	—	—	—	200	319
1.45	1.70	1.98	—	2.62	—	3.34	320
—	—	—	—	—	—	—	321
12.5×10^{-2}	16.4×10^{-2}	19.7×10^{-2}	—	30.2×10^{-2}	—	43.6×10^{-2}	322
75	85	95	—	115	—	138.8	323
5.6×10^{-3}	—	—	—	—	—	—	324
3.52	—	7.39	—	43.25	—	69	325
103.5	109.3	115.5	121.4	127.2	133.1	138.9	326
—	15.98	—	—	—	—	62.8	327
2.3	3.5	4.85	6.72	9.2	12.7	18	328
116.7	155.6	200	251	309	375	452	329

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
330	Rb_2PtCl_6	—	$13.7 \times$ $\times 10^{-3}$	$20.0 \times$ $\times 10^{-3}$	$28.2 \times$ $\times 10^{-3}$	$39.7 \times$ $\times 10^{-3}$
331	Rb_2SO_4	—	36.4	42.6	48.2	53.5
332	SO_2	—	22.83	16.21	11.29	7.81
333	$SbCl_3$	—	601.6	—	931.5	1068.0
334	SbF_3	—	384.7	—	444.7	563.6
335	$SnCl_2$	$2H_2O$	83.9	—	269.8 (15 °C)	—
336	SnI_2	—	—	—	1.0	1.2
337	$SnSO_4$	—	—	—	19	—
338	$SrBr_2$	$6H_2O$	85.2	93.0	102.4	111.9
339	$Sr(C_2H_3O_2)_2$	$4H_2O$	36.9	43.61	—	—
340	$Sr(C_2H_3O_2)_2$	$^1/_2H_2O$	—	42.95	41.6	39.5
341	$SrCl_2$	$6H_2O$	43.5	47.7	52.9	58.7
342	$SrCl_2$	$2H_2O$	—	—	—	—
343	SrI_2	$6H_2O$	165.3	—	177.8	—
344	SrI_2	$2H_2O$	—	—	—	—
345	$Sr(NO_2)_2$	H_2O	52.7	—	63.95	—
346	$Sr(NO_3)_2$	$4H_2O$	40.1	—	70.5	—
347	$Sr(NO_3)_2$	—	—	—	—	88.6
348	$Sr(OH)_2$ (calculated for SrO)	$8H_2O$	0.35	0.48	0.69	1.01
349	$Th(SO_4)_2$	$9H_2O$	0.74	0.98	1.38	1.995
350	$Th(SO_4)_2$	$8H_2O$	1.0	1.25	1.62	—
351	$Th(SO_4)_2$	$6H_2O$	1.50	—	1.90	2.45
352	$Th(SO_4)_2$	$4H_2O$	—	—	—	—
353	$Th(SeO_4)_2$	—	0.498	—	—	—
354	$TlBrO_3$	—	—	—	$3.46 \times$ $\times 10^{-3}$	—
355	$TlCl$	—	0.21	0.25	0.33	0.42
356	$TlClO_3$	—	2.0	—	3.92	—
357	$TlClO_4$	—	6.0	8.04	—	19.72
358	$TlIO_3$	—	—	—	0.058	—
359	$TlNO_3$	—	3.91	6.22	9.55	14.3

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
56.5×10^{-3}	—	99.7×10^{-3}	—	182×10^{-3}	—	334×10^{-3}	330
58.5	63.1	67.4	71.4	75.0	78.7	81.8	331
5.41	4.5	3.2	2.6	2.1	1.8	—	332
1368.0	1917.0	4531.0	—	∞	—	—	333
—	—	—	—	—	—	—	334
—	—	—	—	—	—	—	335
1.4	1.7	2.1	2.5	3.0	3.4	4.0	336
—	—	—	—	—	—	18	337
123.2	135.8	150.0	—	181.8	—	222.5	338
—	—	—	—	—	—	—	339
—	37.35	—	36.24	36.10	36.24	36.4	340
65.3	72.4	81.8	—	—	—	—	341
—	—	—	85.9	90.5	—	100.8	342
191.5	—	217.5	—	270.4	—	—	343
—	—	—	—	—	365.2	383.1	344
—	83.5	97.2	—	—	130.4	138.7	345
—	—	—	—	—	—	—	346
90.1	—	93.8	96	98	100	—	347
1.50	2.18	3.13	4.53	7.03	13.6	24.2	348
2.998	5.22	—	—	—	—	—	349
—	—	—	—	—	—	—	350
—	—	6.64	—	—	—	—	351
4.04	2.54	1.63	1.09	—	—	—	352
—	—	—	—	—	—	—	353
7.36×10^{-2}	—	—	—	—	—	—	354
0.52	0.63	0.8	—	1.2	—	1.8	355
—	12.67	—	—	36.65	—	57.31	356
—	39.62	—	65.32	81.49	—	166.6	357
—	—	—	—	—	—	—	358
20.9	30.4	46.2	69.5	111.0	200.0	414.0	359

No.	Formula	S. Ph.	Tempera			
			0	10	20	30
			Solubility of an *anhydrous* substance in			
360	$TlOH$	—	25.44	—	—	39.9
361	Tl_2SO_4 . . .	—	2.70	3.70	4.87	6.16
362	Tl_2SeO_4 . . .	—	—	2.13	2.8	—
363	$UO_2(NO_3)_2$	$6H_2O$	98.0	108.3	125.7	—
364	$Yb_2(SO_4)_3$ . .	$8H_2O$	44.2	—	38.4	—
365	$ZnBr_2$ . . .	$2H_2O$	389.0	—	446.4	528.1
366	$ZnBr_2$ . . .	—	—	—	—	—
367	$ZnCl_2$	$3H_2O$	207.7	—	—	—
368	$ZnCl_2$	$2\frac{1}{2}H_2O$	—	271.7	367.3	—
369	$ZnCl_2$	—	—	—	—	—
370	$Zn(ClO_3)_2$ . .	$6H_2O$	145.1	152.5	—	—
371	$Zn(ClO_3)_2$ . .	$4H_2O$	—	—	200.3	209.2
372	ZnI_2	$2H_2O$	430.7	457.3	484.9	—
373	ZnI_2	—	429.3	—	—	—
374	$Zn(NO_3)_2$ . .	$6H_2O$	94.77	—	118.4	—
375	$Zn(NO_3)_2$ . .	$3H_2O$	—	—	—	—
376	$ZnBO_4$ . . .	$7H_2O$	41.9	47.0	54.4	—
377	$ZnSO_4$ . . .	$6H_2O$	—	—	—	—
378	$ZnSO_4$ . . .	H_2O	—	—	—	—

Table 8 (continued)

ture, °C							No.
40	50	60	70	80	90	100	
100 g of water at a given temperature, g							
49.5	—	73.8	—	106.0	126.1	148.3	360
—	9.21	10.92	12.74	14.61	16.53	18.45	361
—	—	—	—	8.5	—	10.86	362
—	203.1	365.2	—	—	426	476	363
21.0	—	10.4	7.22	6.92	5.83	4.67	364
—	—	—	—	—	—	—	365
592.6	—	618.4	—	644.6	—	672.0	366
—	—	—	—	—	—	—	367
—	—	—	—	—	—	—	368
452.5	—	488.3	—	541.1	—	614.4	369
—	—	—	—	—	—	—	370
223.1	273.2	—	—	—	—	—	371
—	—	—	—	—	—	—	372
445.2	—	467.3	—	490.0	—	510.5	373
—	—	—	—	—	—	—	374
206.9	—	—	—	—	—	—	375
—	—	—	—	—	—	—	376
70.1	77.0	—	—	—	—	—	377
—	—	—	—	86.6	83.5	80.8	378

Table 9

Solubilities of Some Inorganic Compounds in Organic Solvents at 18-25 °C

Solubilities are expressed in grams of an anhydrous substance (if there are no other indications) per 100 g of a pure anhydrous solvent

Formula	Solubility in				
	ethanol (absolute)	methanol	acetone	pyridine	other solvents
$AgBr$	1.6×10^{-8}	7×10^{-7}	—	—	—
$AgCl$	1.5×10^{-6}	6×10^{-6}	1.3×10^{-6}	1.95	—
AgI	6×10^{-9}	2×10^{-7}	—	—	—
$AgNO_3$	2.1	3.8	0.44	34	Benzene: 0.02; phenol: 30
$AlBr_3$	—	—	—	4.0	Benzene: 125; carbon disulphide: 150
$AlCl_3$	—	—	—	—	Benzene: 0.02; carbon tetrachloride: 0.01; chloroform: 0.05
AlI_3	—	—	—	0.83	—
$Al_2(SO_4)_3$	—	—	—	—	Ethylene glycol: 16.8
$BaBr_2$	3.6	41	0.026	—	Isoamyl alcohol: 0.02
$BaCl_2$	—	2.2	—	—	Glycerin: 9.8
BaI_2	77	—	—	8.2	—
$Ba(NO_3)_2$	1.8×10^{-3}	0.06	5×10^{-8}	—	—
$BiCl_3$	—	—	18.0	—	Ethyl acetate: 1.8
BiI_3	3.5	—	—	—	—
$Bi(NO_3)_3 \cdot 5H_2O$	—	—	41.7	—	—
$CaBr_2$	53.8	56.2	2.73	—	Isoamyl alcohol: 25.6

Table 9 (continued)

Formula	Solubility in				
	ethanol (absolute)	methanol	acetone	pyridine	other solvents
$CaCl_2$	25.8	29.2	0.01	1.69	Isoamyl alcohol: 7.0
CaI_2	—	127	89	—	—
$Ca(NO_3)_2$	51	138	16.9	—	Amyl alcohol: 7.5
$CaSO_4$	—	—	—	—	Glycerin: 5.2
$CdBr_2$	30	16.1	18.1	—	Diethyl ether: 0.4
$CdCl_2$	1.5	2.7	—	0.70	—
CdI_2	113	223	42.8	0.45	Diethyl ether: 0.2
$CdSO_4$	0.03	0.035	—	—	—
$CoBr_2$	77	43	64	—	—
$CoCl_2$	54	40	3.0	0.6	Diethyl ether: 0.02
$Co(NO_3)_2$	—	—	—	—	Ethylene glycol: 400
$CoSO_4$	0.02	0.40	—	—	—
$CuCl_2$	55.5	57.5	2.96	0.34	Diethyl ether: 0.11; isoamyl alcohol: 12
CuI	—	—	—	1.74	—
$CuSO_4$	—	1.5	—	—	—
$FeBr_2$	—	—	—	0.5	—
$FeCl_3$	145	150	62.9	—	—
$Fe_2(SO_4)_3 \cdot 9H_2O$	12.7	—	—	—	—
$FeSO_4$	—	—	—	—	Ethylene glycol: 6.0
H_3BO_3	11	—	0.5	7.1	Glycerin: 22; dioxane: 1.3
HCl	69.5	88.7	—	—	Diethyl ether: 33.2; benzene: 1.9
H_3PO_4	—	—	—	—	Diethyl ether: 525
$HgBr_2$	30	60	51	39.6	Benzene: 0.7
$Hg(CN)_2$	9.5	44.1	10.3	65	—

Formula	Solubility in				
	ethanol (absolute)	methanol	acetone	pyridine	other solvents
$HgCl_2$	47	67	141	25	Diethyl ether: 7
HgI_2	2.2	3.8	3.4	31	Chloroform: 0.07; diethyl ether: 0.7
I_2	26	—	—	—	Chloroform: 2.7; carbon tetrachloride: 2.5; carbon disulphide: 16
KBr	0.46	2.1	0.03	—	Isoamyl alcohol: 0.002
KCN	0.88	4.91	—	—	Glycerin: 32
KCl	0.03	0.5	9.0×10^{-5}	—	Glycerin: 3.7; propyl alcohol: 0.006
KF	0.11	0.19	2.2	—	Propyl alcohol: 0.34
KI	1.75	16.4	2.35	0.3	Glycerin: 40; ethylene glycol: 50
KNO_3	—	—	—	—	Trichloroethylene: 0.01
KOH	39	55	—	—	—
KSCN	—	—	20.8	6.15	—
LiBr	70	—	18.1	—	Ethylene glycol: 60
LiCl	25	43.4	1.2	12	Glycerin: 11
LiI	250	343	43	—	Ethylene glycol: 39
$LiNO_3$	—	—	31	33	Isoamyl alcohol: 10
$MgBr_2$	15.1	27.9	2.0	0.5	Diethyl alcohol: 2.5
$MgCl_2$	5.6	16.0	—	—	—
$MgSO_4$	0.025	0.3	—	—	Glycerin: 26
$MgSO_4 \cdot 7H_2O$	—	43	—	—	—
$MnCl_2$	—	—	—	1.3	—
$MnSO_4$	0.01	0.13	—	—	—
NH_3	12.8	24	—	—	—
NH_4Br	3.4	12.5	—	—	—

Table 9 (continued)

Formula	Solubility in				
	ethanol (absolute)	methanol	acetone	pyridine	other solvents
NH_4Cl	0.6	3.3	—	—	—
NH_4ClO_4	1.9	6.8	2.2	—	—
NH_4NO_3	2.5	17.1	—	0.3	—
NH_4SCN	23.5	59	—	—	—
NH_4I	26.3	—	—	—	—
$NaBF_4$	0.47	4.4	—	—	—
$NaBr$	2.4	16.7	0.008	—	Diethyl ether: 0.08; amyl alcohol: 0.12
Na_2CO_3	—	—	—	—	Glycerin: 98
$NaCl$	0.1	1.5	3×10^{-5}	—	Ethylene glycol: 46.5
Na_2CrO_4	—	0.36	—	—	—
NaF	0.10	0.42	1×10^{-4}	—	—
NaI	46	72.7	26	—	—
$NaNO_2$	0.31	4.4	—	—	—
$NaNO_3$	0.04	0.43	—	—	—
$NaOH$	17.3	31	—	—	—
$NaSCN$	20	35	7	—	—
Na_2SO_4	0.006	0.02	—	—	—
$NiBr_2$	—	35	0.80	—	—
$NiCl_2$	10	—	—	—	Ethylene glycol: 18
$Ni(NO_3)_2$	—	—	—	—	Ethylene glycol: 8
$NiSO_4$	0.02	0.08	—	—	Ethylene glycol: 10
P	0.3	—	0.14	—	Carbon disulphide: 900; benzene: 3.2; carbon tetrachloride: 1.2; diethyl ether: 1.0; glycerin: 0.3

Table 9 (continued)

Formula	Solubility in				
	ethanol (absolute)	methanol	acetone	pyridine	other solvents
$PbBr_2$	—	—	—	0.6	—
$PbCl_2$	—	—	—	0.5	—
PbI_2	—	—	0.02	0.2	—
$Pb(NO_3)_2$	0.04	1.4	—	7	—
S	0.05	0.03	2.1	1.5	Carbon disulphide: 43; carbon tetrachloride: 0.85; chloroform: 1.2; benzene: 1.7; glycerin: 0.14
SbF_3	—	160	70	—	Benzene: 5×10^{-4}
$SbCl_3$	—	—	538	—	Benzene: 42
$SnCl_2$	—	—	56	—	Ethyl acetate: 4.4
$SrBr_2$	64	117	0.6	—	Isoamyl alcohol: 31
SrI_2	4	—	—	—	—
$Sr(NO_3)_2$	0.009	—	—	0.7	Isopropyl alcohol: 0.002
$UO_2(NO_3)_2$	3.3	—	1.5	—	Diethyl ether: 0.96
UO_2SO_4	—	0.73	—	—	—
$ZnBr_2$	—	—	365	4.4	—
$ZnCl_2$	—	—	43.3	2.6	Glycerin: 50
ZnI_2	—	—	—	12.6	Glycerin: 40
$ZnSO_4$	0.03	0.6	—	—	Glycerin: 35

Table 10

Solubility Products of the Chief Sparingly Soluble Substances

The solubility product (SP) of substance Ct_mAn_n, which breaks up into ions according to the equation

$$Ct_mAn_n \rightleftarrows mCt + nAn$$

is $SP = a_{Ct}^m \cdot a_{An}^n$, where a_{Ct} is the activity of cation Ct, and a_{An} is the activity of anion An. The indicator of the solubility product pSP is the logarithm of the solubility product taken with an inverse sign.

When calculating the solubility of a sparingly soluble salt in water or in a solution of other salts by the value of the solubility product, account must be taken of: (1) the reaction of cations being formed with the hydroxyl ions of water; (2) the reaction of anions being formed with hydrogen ions; (3) the ionic strength of a solution on which the activity coefficients depend, and in some cases also (4) the potentialities of complex-ion formation. The ways of making such calculations are described in the textbooks of analytical chemistry.

In addition, *account must be taken of the presence, in the solution, of non-dissociated molecules of a dissolved salt whose concentrations are found by dividing the SP by the corresponding value of K* (Table 38; figures marked with an asterisk).

Formula of substance	SP	pSP=—log SP
$Ac(C_2O_4)_3$	2×10^{-24}	23.7
$Ac(OH)_3$	1×10^{-15}	15
Ag_3AsO_3	1×10^{-17}	17
Ag_3AsO_4	1×10^{-22}	22
$AgBO_2$	4×10^{-1}	0.4
$AgBr$	5.3×10^{-13}	12.28
$AgBrO_3$	5.5×10^{-5}	4.26
$AgC_2H_3O_2$	4×10^{-3}	2.4
$AgCN$	1.4×10^{-16}	15.84
Ag_2CO_3	8.2×10^{-12}	11.09
$Ag_2C_2O_4$	3.5×10^{-11}	10.46
$AgCl$	1.78×10^{-10}	9.75
$AgClO_2$	2×10^{-4}	3.7
$AgClO_3$	5.0×10^{-2}	1.3
Ag_2CrO_4	1.1×10^{-12}	11.95
$Ag_2Cr_2O_7$	1×10^{-10}	10
$Ag_3Fe(CN)_6$	1×10^{-22}	22

Table 10 (continued)

Formula of substance	SP	pSP = −log SP
$Ag_4Fe(CN)_6$	1.5×10^{-41}	40.82
$Ag_2HVO_4(2Ag^+, HVO_4^{2-})$	2×10^{-14}	13.7
AgI	8.3×10^{-17}	16.08
$AgIO_3$	3.0×10^{-8}	7.52
$AgMnO_4$	1.6×10^{-3}	2.79
Ag_2MoO_4	2.8×10^{-12}	11.55
AgN_3	2.9×10^{-9}	8.54
$AgNO_2$	1.6×10^{-4}	3.80
$Ag_2O(Ag^+, OH^-)$	1.6×10^{-8}	7.80
$AgOCN$	2.3×10^{-7}	6.64
$Ag_2PO_3F(2Ag^+, PO_3F^{2-})$	8.9×10^{-4}	3.05
Ag_3PO_4	1.3×10^{-20}	19.89
$AgReO_4$	7.95×10^{-5}	4.10
Ag_2S	6.3×10^{-50}	49.20
$AgSCN$	1.1×10^{-12}	11.97
Ag_2SO_3	1.50×10^{-14}	13.82
$AgSO_3NH_2(Ag^+, SO_3NH_2^-)$	1×10^{-1}	1
Ag_2SO_4	1.6×10^{-5}	4.80
$AgSeCN$	4.0×10^{-16}	15.40
Ag_2SeO_3	9.0×10^{-16}	15.01
Ag_2SeO_4	5.6×10^{-8}	7.25
$AgVO_3$	5×10^{-7}	6.3
Ag_2WO_4	5.5×10^{-12}	11.26
$AlAsO_4$	1.6×10^{-16}	15.80
$Al(OH)_3(Al^{3+}, 3OH^-)$	1×10^{-32}	32.0
$(AlOH^{2+}, 2OH^-)$	1×10^{-23}	23.0
(H^+, AlO_2^-)	1.6×10^{-13}	12.80
$AlPO_4$	5.75×10^{-19}	18.24
$Am(OH)_3$	2.7×10^{-20}	19.57
$Am(OH)_4$	1×10^{-56}	56
$AuBr$	5.0×10^{-17}	16.3
$AuBr_3$	4.0×10^{-36}	35.4
$AuCl$	2.0×10^{-13}	12.7
$AuCl_3$	3.2×10^{-25}	24.5
$Au(OH)_3$	5.5×10^{-46}	45.26
AuI	1.6×10^{-23}	22.8
AuI_3	1×10^{-46}	46
$Ba_3(AsO_4)_2$	7.8×10^{-51}	50.11
$Ba(BrO_3)_2$	5.5×10^{-6}	5.26
$BaCO_3$	5.1×10^{-9}	8.29
BaC_2O_4	1.1×10^{-7}	6.96
$BaCrO_4$	1.2×10^{-10}	9.93
BaF_2	1.1×10^{-6}	5.98
$Ba_2Fe(CN)_6$	3×10^{-8}	7.5
$Ba(IO_3)_2$	1.50×10^{-9}	8.82

Table 10 (continued)

Formula of substance	SP	pSP = −log SP
$BaMnO_4$	2.5×10^{-10}	9.60
$BaMoO_4$	4×10^{-8}	7.40
$Ba(NO_3)_2$	4.5×10^{-3}	2.35
$Ba(OH)_2$	5.0×10^{-3}	2.3
$BaPO_3F(Ba^{2+}, PO_3F^{2-})$	4×10^{-7}	6.4
$Ba_3(PO_4)_2$	6.03×10^{-39}	38.22
$Ba_2P_2O_7$	3×10^{-11}	10.5
$BaPt(CN)_4$	4×10^{-3}	2.4
$Ba(ReO_4)_2$	5.25×10^{-2}	1.28
$BaSO_3$	8.0×10^{-7}	6.1
$BaSO_4$	1.1×10^{-10}	9.97
BaS_2O_3	1.6×10^{-5}	4.79
$BaSeO_4$	2.8×10^{-11}	10.55
$BeCO_3$	1×10^{-3}	3
$BeMoO_4$	3.2×10^{-2}	1.50
$Be(OH)_2(Be^{2+}, 2OH^-)$	6.3×10^{-22}	21.2
$(BeOH^+, OH^-)$	2×10^{-14}	13.7
$BiAsO_4$	2.8×10^{-10}	9.36
BiI_3	8.1×10^{-19}	18.09
$BiOCl(BiO^+, Cl^-)$	7×10^{-9}	8.85
$(BiOCl + H_2O = Bi^{3+} + 2OH^- + Cl^-)$	1.8×10^{-31}	30.75
$BiOOH(BiO^+. OH^-)$	4×10^{-10}	9.4
$Bi(OH)_3$	3.2×10^{-32}	31.5
$BiPO_4$	1.3×10^{-23}	22.90
Bi_2S_3	1×10^{-97}	97
$Ca_3(AsO_4)_2$	6.8×10^{-19}	18.17
$CaC_4H_4O_6$ (tartrate)	7.7×10^{-7}	6.11
$CaCO_3$	4.8×10^{-9}	8.32
CaC_2O_4	2.3×10^{-9}	8.64
$CaCrO_4$	7.1×10^{-4}	3.15
CaF_2	4.0×10^{-11}	10.40
$CaHPO_4(Ca^{2+}, HPO_4^{2-})$	2.7×10^{-7}	6.57
$Ca(H_2PO_4)_2(Ca^{2+}, 2H_2PO_4^-)$	1×10^{-3}	3
$Ca(NH_4)_2Fe(CN)_6$	4×10^{-8}	7.4
$Ca(IO_3)_2$	7.0×10^{-7}	6.15
$Ca(OH)_2(Ca^{2+}, 2OH^-)$	5.5×10^{-6}	5.26
$(CaOH^+, OH^-)$	1.4×10^{-4}	3.86
$Ca_3(PO_4)_2$	2.0×10^{-29}	28.70
$CaPO_3F(Ca^{2+}, PO_3F^{2-})$	4×10^{-3}	2.4
$Ca_5(PO_4)_3OH$	1.6×10^{-58}	57.8
$CaSO_3$	1.3×10^{-8}	7.89
$CaSO_4$	9.1×10^{-6}	5.04
$CaSeO_3$	4.7×10^{-6}	5.53

Table 10 (continued)

Formula of substance	SP	pSP=—log SP
$CaSiF_6$	8.1×10^{-4}	3.09
$CaWO_4$	9.0×10^{-9}	8.06
$Cd_3(AsO_4)_2$	2.2×10^{-33}	32.66
$Cd(CN)_2$	1.0×10^{-8}	8.0
$CdCO_3$	5.2×10^{-12}	11.3
CdC_2O_4	1.5×10^{-8}	7.8
$Cd_2Fe(CN)_6$	3.2×10^{-17}	16.49
$Cd(NH_3)_6(BF_4)_2$	2×10^{-6}	5.7
$Cd(OH)_2$ (freshly-precipitated)	2.2×10^{-14}	13.66
$Cd(OH)_2$ (after ageing)	5.9×10^{-15}	14.23
CdS	7.9×10^{-27}	26.10
$CdSeO_3$	1.30×10^{-9}	8.89
$CdWO_4$	2×10^{-6}	5.7
$Ce_2(C_2O_4)_3$	2.5×10^{-29}	28.60
$Ce(IO_3)_3$	3.2×10^{-10}	9.50
$Ce(IO_3)_4$	5×10^{-17}	16.3
$Ce(OH)_3$	1.5×10^{-20}	19.82
$CeO_2(CeO^{2+}, 2OH^-)$	1×10^{-24}	24.0
$CeO_2(Ce^{4+}, 4OH^-)$	2.5×10^{-51}	50.6
$Ce_2(SO_4)_3$	2×10^{-2}	1.7
$Ce_2(SeO_3)_3$	3.75×10^{-25}	24.43
$Co_3(AsO_4)_2$	7.6×10^{-29}	28.12
$CoCO_3$	1.4×10^{-13}	12.84
CoC_2O_4	6.3×10^{-8}	7.2
$Co_2Fe(CN)_6$	1.8×10^{-15}	14.74
$CoHg(SCN)_4[Co^{2+}, Hg(SCN)_4^{2-}]$	1.50×10^{-6}	5.82
$Co(IO_3)_2$	1.0×10^{-4}	4.0
$Co(NH_3)_6(BF_4)_2$	4×10^{-6}	5.4
$Co(NH_3)_6(ReO_4)_3$	1.7×10^{-12}	11.77
$Co(OH)_2$ (blue)	6.3×10^{-15}	14.20
$Co(OH)_2$ (pink, freshly-precipitated)	2.0×10^{-15}	14.80
$Co(OH)_2$ (pink, after ageing)	2.0×10^{-16}	15.70
$Co(OH)_3$	4×10^{-45}	44.4
CoS α	4.0×10^{-21}	20.40
CoS β	2.0×10^{-25}	24.70
$CoSeO_3$	1.6×10^{-7}	6.8
$CrAsO_4$	7.8×10^{-21}	20.11
$Cr(NH_3)_6(BF_4)_3$	6.2×10^{-5}	4.21
$Cr(NH_3)_6(MnO_4)_3$	4.0×10^{-8}	7.40
$Cr(NH_3)_6(SO_3F)_3$	4.3×10^{-4}	3.9
$Cr(NH_3)_6(ReO_4)_3$	7.7×10^{-12}	11.11

Table 10 (continued)

Formula of substance	SP	pSP=—log SP
$Cr(OH)_2$	1.0×10^{-17}	17.0
$Cr(OH)_3(Cr^{3+}, 3OH^-)$	6.3×10^{-31}	30.20
$(CrOH^{2+}, 2OH^-)$	6.3×10^{-21}	20.20
$CrPO_4$ (violet)	1.0×10^{-17}	17.00
$CrPO_4$ (green)	2.4×10^{-23}	22.62
$CsAuCl_4(Cs^+, AuCl_4^-)$	1×10^{-3}	3
$CsBF_4(Cs^+, BF_4^-)$	2×10^{-5}	4.7
$CsBH_4(Cs^+, BH_4^-)$	2.5×10^{-7}	6.6
$CsBrO_3$	2×10^{-2}	1.7
$CsClO_3$	4×10^{-2}	1.4
$CsClO_4$	4×10^{-3}	2.4
$Cs_3Co(NO_2)_6[3Cs^+, Co(NO_2)_6^{3-}]$	5.8×10^{-16}	15.24
$CsHgCl_3(Cs^+, HgCl_3^-)$	2×10^{-3}	2.7
$CsIO_3$	1.0×10^{-2}	2.0
$CsIO_4$	4.4×10^{-3}	2.36
$CsMnO_4$	9.1×10^{-5}	4.08
Cs_2PtCl_6	3×10^{-8}	7.44
Cs_2PtF_6	2.39×10^{-6}	5.62
$CsReO_4$	4.0×10^{-4}	3.40
Cs_2SiF_6	1.26×10^{-5}	4.90
$Cs_2SnCl_6(2Cs^+, SnCl_6^{2-})$	3.6×10^{-8}	7.44
$Cu_3(AsO_4)_2$	7.6×10^{-36}	35.12
$CuBr$	5.25×10^{-9}	8.28
$CuCN$	3.2×10^{-20}	19.49
$CuCO_3$	2.5×10^{-10}	9.6
CuC_2O_4	3×10^{-8}	7.5
$CuCl$	1.2×10^{-6}	5.92
$CuCrO_4$	3.6×10^{-6}	5.44
$Cu_2Fe(CN)_6$	1.3×10^{-16}	15.89
CuI	1.1×10^{-12}	11.96
$Cu(IO_3)_2$	7.4×10^{-8}	7.13
CuN_3	5.0×10^{-9}	8.3
$Cu_2O(2Cu^+, OH^-)$	1×10^{-14}	14.0
$Cu(OH)_2(Cu^{2+}, 2OH^-)$	2.2×10^{-20}	19.66
$(CuOH^+, OH^-)$	2.2×10^{-13}	12.66
$Cu_2(OH)_2CO_3$	1.7×10^{-34}	33.78
$Cu_2P_2O_7$	8.3×10^{-16}	15.08
CuS	6.3×10^{-36}	35.20
Cu_2S	2.5×10^{-48}	47.60
$CuSCN$	4.8×10^{-15}	14.32
$CuSe$	1×10^{-49}	49
$CuSeO_3$	2.1×10^{-8}	7.68
$CuWO_4$	1×10^{-5}	5
$FeAsO_4$	5.8×10^{-21}	20.24

Table 10 (continued)

Formula of substance	SP	pSP=—log SP
$FeCO_3$	3.47×10^{-11}	10.46
FeC_2O_4	2×10^{-7}	6.7
$Fe_4[Fe(CN)_6]_3$	3.0×10^{-41}	40.52
$Fe(OH)_2(Fe^{2+}, 2OH^-)$	1×10^{-15}	15.0
$(FeOH^+, OH^-)$	5×10^{-10}	9.3
$Fe(OH)_3(Fe^{3+}, 3OH^-)$	3.2×10^{-38}	37.50
$(FeOH^{2+}, 2OH^-)$	2×10^{-26}	25.70
$[Fe(OH)_2^+, OH^-]$	4×10^{-17}	16.40
$FePO_4$	1.30×10^{-22}	21.89
FeS	5×10^{-18}	17.3
$FeS_2(Fe^{2+}, S_2^{2-})$	6.3×10^{-31}	30.2
$FeSe$	1×10^{-26}	26
$Fe_2(SeO_3)_3$	2×10^{-31}	30.7
$Ga_4[Fe(CN)_6]_3$	1.5×10^{-34}	33.82
$Ga(OH)_3$	7.1×10^{-36}	35.15
$GeO_2(Ge^{4+}, 4OH^-)$	1×10^{-57}	57.0
GeS	3×10^{-35}	34.5
$HfO(OH)_2(HfO^{2+}, 2OH^-)$	4×10^{-26}	25.4
$Hg_2Br_2(Hg_2^{2+}, 2Br^-)$	5.8×10^{-23}	22.24
$Hg_2CO_3(Hg_2^{2+}, CO_3^{2-})$	8.9×10^{-17}	16.05
$Hg_2C_2O_4(Hg_2^{2+}, C_2O_4^{2-})$	1×10^{-13}	13
$Hg_2Cl_2(Hg_2^{2+}, 2Cl^-)$	1.3×10^{-18}	17.88
$Hg_2CrO_4(Hg_2^{2+}, CrO_4^{2-})$	5.0×10^{-9}	8.70
$Hg_2I_2(Hg_2^{2+}, 2I^-)$	4.5×10^{-29}	28.35
$Hg_2(IO_3)_2(Hg_2^{2+}, 2IO_3^-)$	2.45×10^{-14}	13.71
$Hg_2HPO_4(Hg_2^{2+}, HPO_4^{2-})$	4.0×10^{-13}	12.40
$HgO(Hg^{2+}, 2OH^-)$	3.0×10^{-26}	25.52
$Hg_2O(Hg_2^{2+}, 2OH^-)$	1.6×10^{-23}	22.8
HgS* (black)	1.6×10^{-52}	51 8
HgS (red)	4.0×10^{-53}	52.40
$Hg_2S(Hg_2^{2+}, S^{2-})$	1×10^{-47}	47.0
$Hg_2(SCN)_2(Hg_2^{2+}, 2SCN^-)$	3.0×10^{-20}	19.52
$Hg_2SO_3(Hg_2^{2+}, SO_3^{2-})$	1×10^{-27}	27.0
$Hg_2SO_4(Hg_2^{2+}, SO_4^{2-})$	6.8×10^{-7}	6.17

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* The solubility products of mercuric salts (with the exception of HgS and HgSe) are not given here, since their very small values can give rise to incorrect ideas about the correspondingly sparing solubilities of these salts. In fact, upon a transition of mercuric salts to a solution, a very small amount of free ions (the product of whose concentrations gives the value of SP) but a relatively great amount of non-dissociated molecules — $Hg(CN)_2$, $HgCl_2$, etc. — are formed.

The degree of dissociation of mercuric salts must be determined according to the constants given in Table 38.

Table 10 (continued)

Formula of substance	SP	pSP=−log SP
$HgSe$	1×10^{-59}	59.0
$Hg_2SeO_3(Hg_2^{2+}, SeO_3^{2-})$	6.3×10^{-15}	14.2
$Hg_2WO_4(Hg_2^{2+}, WO_4^{2-})$	1.10×10^{-17}	16.96
$In_4[Fe(CN)_6]_3$	1.9×10^{-44}	43.72
$In(IO_3)_3$	3×10^{-3}	2.5
$In(OH)_3$	5×10^{-34}	33.3
In_2S_3	1×10^{-88}	88
$IrO_2(Ir^{4+}, 4OH^-)$	1.6×10^{-72}	71.8
$Ir_2O_3(2Ir^{3+}, 3OH^-)$	2×10^{-48}	47.7
IrS_2	1×10^{-75}	75
$K_3AlF_6(3K^+, AlF_6^{3-})$	1.6×10^{-9}	8.80
$KBF_4(K^+, BF_4^-)$	2×10^{-3}	2.7
$KBH_4(K^+, BH_4^-)$	1.3×10^{-3}	2.9
$K(C_6H_5)_4B[K^+, (C_6H_5)_4B^-]$	2.25×10^{-8}	7.65
$KClO_4$	1.1×10^{-2}	1.97
$K_3Co(NO_2)_6[3K^+, Co(NO_2)_6^{3-}]$	4.3×10^{-10}	9.37
$K_2NaCo(NO_2)_6[2K^+, Na^+, Co(NO_2)_6^{3-}]$	2.2×10^{-11}	10.66
$K_2GeF_6(2K^+, GeF_6^{2-})$	3.0×10^{-5}	4.52
$K_2HfF_6(2K^+, HfF_6^{2-})$	2×10^{-3}	2.7
$K_2IrCl_6(2K^+, IrCl_6^{2-})$	6.8×10^{-5}	4.17
KIO_4	8.3×10^{-4}	3.08
$K_2PdCl_4(2K^+, PdCl_4^{2-})$	1.6×10^{-5}	4.9
$K_2PdCl_6(2K^+, PdCl_6^{2-})$	6.0×10^{-6}	5.2
$K_2PtCl_4(2K^+, PtCl_4^{2-})$	8×10^{-3}	2.1
$K_2PtCl_6(2K^+, PtCl_6^{2-})$	1.1×10^{-5}	4.96
$K_2PtF_6(2K^+, PtF_6^{2-})$	2.9×10^{-5}	4.54
$KReO_4$	1.9×10^{-3}	2.72
K_2SiF_6	8.7×10^{-7}	6.06
$K_2TiF_6(2K^+, TiF_6^{2-})$	5×10^{-4}	3.3
$K_2ZrF_6(2K^+, ZrF_6^{2-})$	5×10^{-4}	3.3
$La(BrO_3)_3$	3×10^{-3}	2.5
$La_2(C_2O_4)_3$	2.5×10^{-27}	26.60
$La(IO_3)_3$	6.2×10^{-12}	11.21
$La_2(MoO_4)_3$	4×10^{-21}	20.4
$La(OH)_3$	2.0×10^{-19}	18.7
La_2S_3	2.0×10^{-13}	12.70
$La_2(SO_4)_3$	3×10^{-5}	4.5
Li_2CO_3	3.98×10^{-3}	2.40
LiF	3.8×10^{-3}	2.42
$LiOH$	4×10^{-2}	1.4
Li_3PO_4	3.2×10^{-9}	8.5
$Mg_3(AsO_4)_2$	2.1×10^{-20}	19.68
$MgCO_3$	2.1×10^{-5}	4.67
MgC_2O_4	8.6×10^{-5}	4.1

Table 10 (continued)

Formula of substance	SP	pSP=−log SP
MgF_2	6.5×10^{-9}	8.19
$Mg(IO_3)_2$	3×10^{-3}	2.5
$MgK_2Fe(CN)_6$	5×10^{-9}	8.3
$Mg(NH_4)_2Fe(CN)_6$	4×10^{-8}	7.4
$MgNH_4PO_4$	2.5×10^{-13}	12.6
$Mg(OH)_2$	6.0×10^{-10}	9.22
(freshly-precipitated)		
$Mg(OH)_2(Mg^{2+}, 2OH^-)$	1.8×10^{-11}	10.74
$(MgOH^+, OH^-)$	2.3×10^{-7}	6.64
(after ageing)		
$Mg_3(PO_4)_2$	1×10^{-13}	13
$MgSO_3$	3×10^{-3}	2.5
$MgSeO_3$	1.30×10^{-5}	4.89
$Mn_3(AsO_4)_2$	1.9×10^{-29}	28.72
$MnCO_3$	1.8×10^{-11}	10.74
MnC_2O_4	5×10^{-6}	5.3
$Mn_2Fe(CN)_6$	7.9×10^{-13}	12.10
$MnNH_4PO_4$	1×10^{-12}	12
$Mn(OH)_2(Mn^{2+}, 2OH^-)$	1.9×10^{-13}	12.72
$(MnOH^+, OH^-)$	1.5×10^{-9}	8.82
$Mn(OH)_3$	1×10^{-36}	36
MnS*	2.5×10^{-10}	9.60
(flesh-coloured)		
MnS*	2.5×10^{-13}	12.60
(green)		
$MnSeO_3$	1.26×10^{-7}	6.9
$Mo(OH)_4$	1×10^{-50}	50.0
$(NH_4)_3AlF_6(3NH_4^+, AlF_6^{3-})$	1.6×10^{-3}	2.80
$(NH_4)_3Co(NO_2)_6[3NH_4^+, Co(NO_2)_6^{3-}]$	7.6×10^{-6}	5.12
$(NH_4)_2IrCl_6$	3×10^{-5}	4.5
$(NH_4)_2PtCl_6$	9×10^{-6}	5.05
Na_3AlF_6	4.1×10^{-10}	9.39
Na_2BeF_4	7×10^{-3}	2.15
$NaIO_4$	3×10^{-3}	2.5
$NaSb(OH)_6[Na^+, Sb(OH)_6^-]$	4×10^{-8}	7.4
Na_2SiF_6	2.8×10^{-4}	3.56
$Ni_3(AsO_4)_2$	3.1×10^{-26}	25.51
$Ni(CN)_2$	3×10^{-23}	22.5
$NiCO_3$	1.3×10^{-7}	6.87
NiC_2O_4	4×10^{-10}	9.4

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* The values of SP_{MnS} are given according to A. Ringbom, "Solubilities of Sulfides" (*Report to Analytical Section IUPAC*, July, 1953); they considerably differ from many of those found earlier, for example for the modification of flesh-coloured: 7×10^{-16} (Bruner, Zawadski), 1.1×10^{-15} (Kapustinsky); for the modification of green colour: 6.2×10^{-22} (Bruner, Zawadski).

Table 10 (continued)

Formula of substance	SP	pSP=−log SP
$Ni(ClO_3)_2$	1×10^{-4}	4
$Ni_2Fe(CN)_6$	1.3×10^{-15}	14.89
$Ni(IO_3)_2$	1.40×10^{-8}	7.85
$Ni(NH_3)_6(BF_4)_2$	1×10^{-6}	6
$Ni(NH_3)_6(ReO_4)_2$	5.1×10^{-4}	3.29
$Ni(OH)_2$ (freshly-precipitated)	2.0×10^{-15}	14.70
$Ni(OH)_2$ (after ageing)	6.3×10^{-18}	17.20
$Ni_2P_2O_7$	1.7×10^{-13}	12.77
NiS α	3.2×10^{-19}	18.50
NiS β	1×10^{-24}	24.0
NiS γ	2.0×10^{-26}	25.70
$NiSeO_3$	1.0×10^{-5}	5.0
$NpO_2(OH)_2(NpO_2^{2+}, 2OH^-)$	2.5×10^{-22}	21.6
$Pb_3(AsO_4)_2$	4.1×10^{-36}	35.39
$PbBr_2$	9.1×10^{-6}	5.04
$Pb(BrO_3)_2$	7.99×10^{-6}	5.10
$PbCO_3$	7.49×10^{-14}	13.13
PbC_2O_4	4.8×10^{-10}	9.32
$PbCl_2$	1.6×10^{-5}	4.79
$PbClF$	2.8×10^{-9}	8.55
$PbCrO_4$	1.8×10^{-14}	13.75
PbF_2	2.7×10^{-8}	7.57
$Pb_2Fe(CN)_6$	3.5×10^{-15}	14.46
PbI_2	1.1×10^{-9}	8.98
$Pb(IO_3)_2$	2.6×10^{-13}	12.58
$PbMoO_4$	4.0×10^{-6}	5.4
$Pb(N_3)_2$	2.6×10^{-9}	8.59
$Pb(OH)_2(Pb^{2+}, 2OH^-)$	1.1×10^{-20}	19.96
$(PbOH^+, OH^-)$	8.7×10^{-14}	13.06
$PbOHBr$	2×10^{-15}	14.7
$PbOHCl$	2×10^{-14}	13.7
$PbO_2(Pb^{4+}, 4OH^-)$	3.0×10^{-66}	65.5
$Pb_3O_4(2Pb^{2+}, PbO_4^{4-})$	5.3×10^{-51}	50.28
$Pb_3(PO_4)_2$	7.9×10^{-43}	42.10
$Pb_5(PO_4)_3Cl$	7.5×10^{-80}	79.12
$PbPO_3F$	1×10^{-7}	7.0
PbS	2.5×10^{-27}	26.60
$Pb(SCN)_2$	2.0×10^{-5}	4.70
$PbSO_4$	1.6×10^{-8}	7.80
PbS_2O_3	4.0×10^{-7}	6.40
$PbSe$	1×10^{-38}	38
$PbSeO_3$	3×10^{-12}	11.5
$PbSeO_4$	1.45×10^{-7}	6.84
$PbWO_4$	4.5×10^{-7}	6.35

Table 10 (continued)

Formula of substance	SP	pSP=−log SP
$Pb(OH)_4$	6.5×10^{-71}	70.2
PoS	5×10^{-29}	28.3
$Po(SO_4)_2$	2.6×10^{-7}	6.58
$PtBr_4$	3×10^{-41}	40.5
$PtCl_4$	8.0×10^{-29}	28.1
$Pt(OH)_2$	1×10^{-35}	5
$PtO_2(Pt^{4+}, 4OH^-)$	1.6×10^{-72}	71.8
PtS	8×10^{-73}	72.1
$Pu(OH)_3$	2×10^{-20}	19.7
$Pu(OH)_4$	1×10^{-52}	52
$PuO_2OH(PuO_2^+, OH^-)$	1×10^{-3}	3
$PuO_2(OH)_2(PuO_2^{2+}, 2OH^-)$	3.2×10^{-21}	20.5
$Pu(IO_3)_4$	5×10^{-13}	12.3
$Ra(IO_3)_2$	8.8×10^{-10}	9.06
$Ra(NO_3)_2$	6.2×10^{-3}	2.21
$RaSO_4$	4.3×10^{-11}	10.37
$RbBF_4$	1×10^{-3}	3.0
$RbBH_4$	2.5×10^{-4}	3.6
$RbBrO_3$	2×10^{-2}	1.7
$RbClO_4$	2.5×10^{-3}	2.60
$Rb_3Co(NO_2)_6[3Rb^+, Co(NO_2)_6^{3-}]$	1.48×10^{-15}	14.83
$RbIO_4$	5.5×10^{-4}	3.26
$RbMnO_4$	2.9×10^{-3}	2.54
$Rb_2PtCl_2(2Rb^+, PtCl_6^{2-})$	9×10^{-8}	7.2
$Rb_2PtF_6(2Rb^+, PtF_6^{2-})$	7.63×10^{-7}	6.12
$RbReO_4$	9.6×10^{-4}	3.02
Rb_2SiF_6	5×10^{-7}	6.3
Rb_2TiF_6	5.5×10^{-5}	4.26
$Rh_2O_3(Rh^{3+}, 3OH^-)$	2×10^{-48}	47.7
$Ru_2O_3(Ru^{3+}, 3OH^-)$	1×10^{-36}	36
$Sb_2O_3(Sb^{3+}, 3OH^-)$	4×10^{-42}	41.4
(SbO^+, OH^-)	7.9×10^{-18}	17.1
Sb_2S_3	1.6×10^{-93}	92.8
$Sc(OH)_3$	1×10^{-27}	27
SnI_2	1.0×10^{-4}	4.0
$Sn(OH)_2(Sn^{2+}, 2OH^-)$	6.3×10^{-27}	26.20
$(SnOH^+, OH^-)$	4.6×10^{-15}	14.34
$Sn(OH)_4$	1×10^{-57}	57
SnS	1×10^{-25}	25.0
$Sr_3(AsO_4)_2$	1.3×10^{-18}	17.79
$SrCO_3$	1.1×10^{-10}	9.96
SrC_2O_4	5.6×10^{-8}	7.25
$SrCrO_4$	3.6×10^{-5}	4.44
SrF_2	2.5×10^{-9}	8.61
$Sr(IO_3)_2$	3.3×10^{-7}	6.48

Table 10 (continued)

Formula of substance	SP	pSP=−log SP
$SrMoO_4$	2×10^{-7}	6.7
$Sr(OH)_2$	3.2×10^{-4}	3.50
$Sr_3(PO_4)_2$	1×10^{-31}	31
$SrPO_3F$	3×10^{-3}	2.5
$SrSO_3$	4×10^{-8}	7.4
$SrSO_4$	3.2×10^{-7}	6.49
$SrSeO_3$	8.5×10^{-7}	6.07
$SrSiF_6$	1.5×10^{-2}	1.82
$SrWO_4$	2.2×10^{-10}	9.77
$Te(OH)_4$	3.0×10^{-54}	53.52
$Th(C_2O_4)_2$	2.0×10^{-5}	4.70
$Th(IO_3)_4$	2.5×10^{-15}	14.6
$Th(OH)_4$	3.2×10^{-45}	44.5
$Th_3(PO_4)_4$	2.57×10^{-79}	78.59
$Th(SO_4)_2$	4×10^{-3}	2.4
$TiO(OH)_2(TiO^{2+}, 2OH^-)$	1×10^{-29}	29
$TlBr$	3.89×10^{-6}	5.41
$TlBrO_3$	3.89×10^{-4}	3.41
Tl_2CO_3	4×10^{-3}	2.4
$TlCl$	1.7×10^{-4}	3.76
$TlClO_4$	4×10^{-2}	1.4
$Tl_3Co(NO_2)_6[3Tl^+, Co(NO_2)_6^{3-}]$	1.0×10^{-16}	16.00
Tl_2CrO_4	9.8×10^{-13}	12.01
$Tl_4Fe(CN)_6$	5×10^{-10}	9.3
TlI	6.5×10^{-8}	7.19
$TlIO_3$	3.1×10^{-6}	5.51
$Tl(OH)_3$	6.3×10^{-46}	45.20
Tl_3PO_4	6.7×10^{-8}	7.18
Tl_2PtCl_6	4×10^{-12}	11.4
$TlReO_4$	1.2×10^{-5}	4.92
Tl_2S	5.0×10^{-21}	20.30
$TlSCN$	1.7×10^{-4}	3.77
Tl_2SO_3	6.3×10^{-4}	3.2
Tl_2SO_4	4×10^{-3}	2.4
$Tl_2S_2O_3$	2.0×10^{-7}	6.70
$TlVO_3$	1×10^{-5}	5
$Tl_4V_2O_7$	1×10^{-11}	11
$UO_2C_2O_4$	4×10^{-4}	3.4
$(UO_2)_2Fe(CN)_6$	7.0×10^{-14}	13.15
$UO_2HAsO_4(UO_2^{2+}, HAsO_4^{2-})$	3.2×10^{-11}	10.50
$UO_2HPO_4(UO_2^{2+}, HPO_4^{2-})$	2.14×10^{-11}	10.67
$UO_2(IO_3)_2$	3×10^{-8}	7.5
UO_2KAsO_4	2.5×10^{-23}	22.60
UO_2KPO_4	7.8×10^{-24}	23.11
$UO_2NH_4AsO_4$	1.7×10^{-24}	23.77

Table 10 (continued)

Formula of substance	SP	pSP = −log SP
$UO_2NH_4PO_4$	4.4×10^{-27}	26.36
UO_2NaAsO_4	1.3×10^{-22}	21.87
$U(OH)_3$	1×10^{-19}	19.0
$U(OH)_4$	1×10^{-45}	45.0
$UO_2(OH)_2(UO_2^{2+}, 2OH^-)$	1×10^{-22}	22.0
$VO(OH)_2$	7.4×10^{-23}	22.13
$V_2O_5(VO_2^+, OH^-)$	1.6×10^{-15}	14.8
$(VO)_3(PO_4)_2$	8×10^{-25}	24.1
$W(OH)_4$	1×10^{-50}	50.0
$Y(OH)_3$	6.3×10^{-25}	24.2
$Zn_3(AsO_4)_2$	1.07×10^{-27}	26.97
$Zn(CN)_2$	2.6×10^{-13}	12.59
$ZnCO_3$	1.45×10^{-11}	10.84
ZnC_2O_4	1.5×10^{-9}	8.8
$Zn_2Fe(CN)_6$	4.1×10^{-16}	15.39
$ZnHg(SCN)_4[Zn^{2+}, Hg(SCN)_4^{2-}]$	2.2×10^{-7}	6.66
$Zn(IO_3)_2$	2.0×10^{-8}	7.7
$Zn(OH)_2(Zn^{2+}, 2OH^-)$	7.1×10^{-18}	17.15
$(ZnOH^+, OH^-)$	1.8×10^{-13}	12.75
$Zn_3(PO_4)_2$	9.1×10^{-33}	32.04
ZnS α (sphalerite)	1.6×10^{-24}	23.80
ZnS β (vurcite)	2.5×10^{-22}	21.60
ZnSe	1×10^{-31}	31
$ZnSeO_3$	2.57×10^{-7}	6.59
$ZrO(OH)_2$	2×10^{-24}	23.7
$Zr(OH)_4(Zr^{4+}, 4OH^-)$	1.1×10^{-54}	53.96
$[Zr(OH)_2^{2+}, 2OH^-]$	3.2×10^{-26}	25.50
$Zr_3(PO_4)_4$	1×10^{-132}	132

Table 11

Activity Coefficients of Various Ions

Ions	Values of activity coefficients at the given ionic strength μ*							
	0.0005	0.001	0.0025	0.005	0.01	0.025	0.05	0.1
Ions of inorganic compounds								
H^+	0.975	0.967	0.950	0.933	0.914	0.88	0.86	0.83
Li^+	0.975	0.965	0.948	0.929	0.907	0.87	0.835	0.80
Rb^+, Cs^+, NH_4^+, Ag^+, Tl^+	0.975	0.964	0.945	0.924	0.898	0.85	0.80	0.75
K^+, Cl^-, Br^-, I^-, CN^-, NO_2^-, NO_3^-	0.975	0.964	0.945	0.925	0.899	0.85	0.805	0.755
OH^-, F^-, HS^-, ClO_3^-, ClO_4^-, BrO_3^-, IO_4^-, MnO_4^-, OCN^-, SCN^-	0.975	0.964	0.946	0.926	0.900	0.855	0.81	0.76
Na^+, $CdCl^+$, ClO_2^-, IO_3^-, HCO_3^-, $H_2PO_4^-$, HSO_3^-, $H_2AsO_3^-$	0.975	0.964	0.947	0.928	0.902	0.86	0.82	0.775
Hg_2^{2+}, SO_4^{2-}, $S_2O_3^{2-}$, $S_4O_6^{2-}$, $S_2O_8^{2-}$, SeO_4^{2-}, CrO_4^{2-}, HPO_4^{2-}	0.903	0.867	0.803	0.740	0.660	0.545	0.445	0.355

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* Ionic strength $\mu = \frac{C_1Z_1^2 + C_2Z_2^2 + C_3Z_3^2 + \ldots + C_nZ_n^2}{2}$, where C_1, C_2, C_3, ..., C_n are the concentrations of all ions present in the solution, and Z_1, Z_2, Z_3, ..., Z_n are the corresponding values of the charges of these ions.

Table 11 (continued)

Ions	Values of activity coefficients at the given ionic strength μ							
	0.0005	0.001	0.0025	0.005	0.01	0.025	0.05	0.1
	Ions of inorganic compounds							
Pb^{2+}, CO_3^{2-}, SO_3^{2-}, MoO_4^{2-}	0.903	0.868	0.805	0.742	0.665	0.55	0.455	0.37
Sr^{2+}, Ba^{2+}, Ra^{2+}, Cd^{2+}, Hg^{2+}, S^{2-}, $S_2O_4^{2-}$, WO_4^{2-}	0.903	0.868	0.805	0.744	0.67	0.555	0.465	0.38
Ca^{2+}, Cu^{2+}, Zn^{2+}, Sn^{2+}, Mn^{2+}, Fe^{2+}, Ni^{2+}, Co^{2+}	0.905	0.870	0.809	0.749	0.675	0.57	0.485	0.405
Mg^{2+}, Be^{2+}	0.906	0.872	0.813	0.755	0.69	0.595	0.52	0.45
PO_4^{3-}, $[Fe(CN)_6]^{3-}$ . . .	0.796	0.725	0.612	0.505	0.395	0.25	0.16	0.095
Al^{3+}, Fe^{3+}, Cr^{3+}, Sc^{3+}, Y^{3+}, La^{3+}, In^{3+}, Ce^{3+}, Pr^{3+}, Nd^{3+}, Sm^{3+} . . .	0.802	0.738	0.632	0.54	0.445	0.325	0.245	0.18
$[Fe(CN)_6]^{4-}$	0.668	0.57	0.425	0.31	0.20	0.10	0.048	0.021
Th^{4+}, Zr^{4+}, Ce^{4+}, Sn^{4+}	0.678	0.588	0.455	0.35	0.255	0.155	0.10	0.065
	Ions of organic compounds							
$HCOO^-$, $H_2C_6H_5O_7^-$, $CH_3NH_3^+$, $(CH_3)_2NH_2^+$.	0.975	0.964	0.946	0.926	0.900	0.855	0.81	0.76
$^-OOCCH_2NH_3^+$, $(CH_3)_3NH^+$, $C_2H_5NH_3^+$	0.975	0.964	0.947	0.927	0.901	0.855	0.815	0.77
CH_3COO^-, $(CH_3)_4N^+$, CH_2ClCOO^-, $NH_2CH_2COO^-$	0.975	0.964	0.947	0.928	0.902	0.86	0.82	0.775

Table 11 (continued)

Ions	Values of activity coefficients at the given ionic strength μ							
	0.0005	0.001	0.0025	0.005	0.01	0.025	0.05	0.1
Ions of organic compounds								
$CHCl_2COO^-$, CCl_3COO^-, $(C_2H_5)_3NH^+$, $C_3H_7NH_3^+$	0.975	0.964	0.947	0.928	0.904	0.865	0.83	0.79
$C_6H_5COO^-$, $C_6H_4OHCOO^-$, $C_6H_4ClCOO^-$, $C_6H_5CH_2COO^-$, $H_2C{=}CHCH_2COO^-$, $(C_2H_5)_4N^+$, $(CH_3)_2C{=}CHCOO^-$, $(C_3H_7)_2NH_2^+$	0.975	0.965	0.948	0.929	0.907	0.87	0.835	0.80
$[OC_6H_2(NO_2)_3]^-$, $(C_3H_7)_3NH^+$	0.975	0.965	0.948	0.930	0.909	0.875	0.845	0.81
$(COO)_2^{2-}$, $HC_6H_5O_7^{2-}$ . . .	0.903	0.867	0.804	0.741	0.662	0.55	0.45	0.36
$H_2C(COO)_2^{2-}$, $(CH_2COO)_2^{2-}$, $(CHOHCOO)_2^{2-}$	0.903	0.868	0.805	0.744	0.67	0.555	0.465	0.38
$C_6H_4(COO)_2^{2-}$, $H_2C(CH_2COO)_2^{2-}$, $CH_2CH_2(COO)_2^{2-}$ . . .	0.905	0.870	0.809	0.749	0.675	0.57	0.485	0.405
$C_6H_5O_7^{3-}$	0.796	0.728	0.616	0.51	0.405	0.27	0.18	0.115

Table 12

Activity Coefficients of Various Ions at High Values of the Ionic Strength of a Solution

(Approximate Values)

The table has been compiled by L. Meites* according to the Davis formula:

$$-\frac{\log f_i}{Z_i^2}=\frac{0.511\sqrt{\mu}}{1+1.5\sqrt{\mu}}-0.2\mu$$

where μ is the ionic strength of a solution, f_i is the activity coefficient of an ion, Z_i is an ion charge (from 1 to 6). A mean value of ion radii was taken as an effective ion radius.

μ	$-\frac{\log f_i}{Z_i^2}$	f_i at Z_i equal to					
		1	2	3	4	5	6
0.05	0.076	0.84	0.50	0.21	0.062	0.013	0.0019
0.1	0.090	0.81	0.44	0.16	0.037	0.0058	0.00060
0.2	0.097	0.80	0.41	0.14	0.028	0.0038	0.00033
0.3	0.094	0.81	0.42	0.14	0.032	0.0046	0.00043
0.4	0.086	0.82	0.45	0.17	0.042	0.0072	0.00082
0.5	0.075	0.84	0.50	0.21	0.062	0.013	0.0020
0.6	0.063	0.87	0.56	0.27	0.098	0.027	0.0054
0.7	0.050	0.89	0.63	0.36	0.16	0.058	0.016
0.8	0.035	0.92	0.72	0.48	0.27	0.13	0.054
0.9	0.020	0.96	0.83	0.66	0.48	0.31	0.19
1.0	0.0044	0.99	0.96	0.91	0.85	0.78	0.69

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* L. Meites, *Handbook of Analytical Chemistry*, London, 1963.

Table 13

Calibration of Glassware

Correction A is equal to the difference between 1000 g (mass of one litre of water in a vacuum at 4 °C) and the mass of one litre of water in a vacuum at a temperature indicated in the first column.

Correction B for weighing in air with the aid of brass weights (the density of brass is 8.4 g/cm^3) is calculated with an allowance that barometric pressure differs little from the standard one (760 mm Hg) and that the relative humidity of air is about 50%. Since with a change in barometric pressure by 10 mm Hg the value of B changes on average by 14 mg, it is necessary, if pressure deviates greatly from 760 mm, to use a more accurate value $B' = B + (P - 760)\,1.4$ mg, where P is the barometric pressure.

Correction C for the expansion (or compression) of a vessel depending on whether the temperature is above or below the standard one (20 °C) is calculated according to the mean expansion coefficient of glass, equal to 25×10^{-6}.

The last column gives the mass of water in air at experiment temperature occupying at 20 °C a volume of one litre. *When calibrating vessels with a smaller capacity, one should take the corresponding part of this mass.*

Temperature, °C	Mass of 1000 ml of water in a vacuum, g ($d \cdot 1000$)	Correction A, g	Correction B, g	Correction C, g	$A+B+C$, g	$1000 - (A+B+C)$, g
9	999.81	0.19	1.10	+0.28	1.57	998.43
10	999.73	0.27	1.09	+0.25	1.61	998.39
11	999.63	0.37	1.09	+0.23	1.69	998.31
12	999.52	0.48	1.09	+0.20	1.77	998.23
13	999.40	0.60	1.08	+0.18	1.86	998.14
14	999.27	0.73	1.08	+0.15	1.96	998.04
15	999.13	0.87	1.07	+0.13	2.07	997.93
16	998.97	1.03	1.07	+0.10	2.20	997.80
17	998.80	1.20	1.07	+0.08	2.35	997.65
18	998.62	1.38	1.06	+0.05	2.49	997.51
19	998.43	1.57	1.06	+0.03	2.66	997.34
20	998.23	1.77	1.05	0.00	2.82	997.18
21	998.02	1.98	1.05	—0.03	3.00	997.00
22	997.80	2.20	1.05	—0.05	3.20	996.80
23	997.57	2.43	1.04	—0.08	3.39	996.61
24	997.33	2.67	1.04	—0.10	3.61	996.39
25	997.08	2.92	1.03	—0.13	3.82	996.18
26	996.82	3.18	1.03	—0.15	4.06	995.94

Table 13 (continued)

Temperature, °C	Mass of 1000 ml of water in a vacuum, g ($d \cdot 1000$)	Correction A, g	Correction B, g	Correction C, g	$A+B+C$, g	$1000-(A+B+C)$, g
27	996.55	3.45	1.03	—0.18	4.30	995.70
28	996.27	3.73	1.02	—0.20	4.55	995.45
29	995.98	4.02	1.02	—0.23	4.81	995.19
30	995.68	4.32	1.01	—0.25	5.08	994.92
31	995.37	4.63	1.01	—0.28	5.36	994.64
32	995.06	4.94	1.01	—0.30	5.65	994.35
33	994.73	5.27	1.00	—0.33	5.94	994.06
34	994.40	5.60	1.00	—0.35	6.25	993.75
35	994.06	5.94	0.99	—0.38	6.55	993.45

Table 14

Calculation of the Results of Volumetric-Analytical Determinations*

One millilitre of a titrating solution titrates N_sE_x mg of a substance being determined (N_s is the normality of the titrating solution**, E_x is the equivalent weight of the substance being determined that is given in the table). If g is the weighed portion of the material being analysed in mg and V is the amount of the titrating solution used in titration, then the percentage of substance x being determined is:

$$x = \frac{VN_sE_x \cdot 100}{g}$$

A. Acid-Base Titrations (Acidimetry and Alkalimetry)

Substances used for titration and the concentrations of their normal solutions:

(a) *Acids*

Formula	HCl	H_2SO_4	HNO_3	$H_2C_2O_4 \cdot 2H_2O$
Concentration of 1*N* solutions (g/l)	36.461	49.039	63.0129	63.0333

(b) *Alkalies*

Formula	$NaOH$	KOH	$Ba(OH)_2 \cdot 8H_2O$
Concentration of 1*N* solutions (g/l)	39.9972	56.109	157.74

Substance being determined	$\frac{E}{M*}$	Equivalent weight, E	log E
Al	1/3	8.99383	95 394
B (titration of H_3BO_3 with phenolphthalein in the presence of mannitol or glycerin)	1	10.811	03 387
$Ba(OH)_2$	1/2	85.675	93 285
$Ba(OH)_2 \cdot 8H_2O$	1/2	157.74	19 794
CO_2	1/2	22.0050	34 252
CO_3	1/2	30.0047	47 719
CH_3COO^-	1	59.0450	77 118

* M=molecular weight.

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* For the use of the table, see p. 462.

** In the notation N_s, E_x, etc., given here and in the following tables, symbol s, written as a subscript, applies to the titrating solutions, and symbol x applies to the titrates of a substance being determined.

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
$CaCO_3$	1/2	50.045	69 936
$Ca(HCO_3)_2$	1/2	81.057	90 879
CaO	1/2	28.040	44 778
$Ca(OH)_2$	1/2	37.047	56 875
H_3BO_3 (with phenolphthalein in the presence of mannitol or glycerin)	1	61.833	79 122
HBr	1	80.912	90 801
$HCHO_2$ (formic acid)	1	46.0259	66 300
$HC_2H_3O_2$ (acetic)	1	60.0530	77 853
$H_2C_4H_4O_4$ (succinic)	1/2	59.045	77 118
$H_2C_4H_4O_6$ (tartaric)	1/2	75.0445	87 532
$H_3C_6H_5O_7$ (citric)	1/3	64.0420	80 646
$H_3C_6H_5O_7 \cdot H_2O$	1/3	70.0473	84 539
$HC_7H_5O_2$ (benzoic)	1	122.125	08 680
$H_2C_2O_4$ (oxalic)	1/2	45.0179	65 339
$H_2C_2O_4 \cdot 2H_2O$	1/2	63.0333	79 957
HCl	1	36.461	56 183
$HClO_4$	1	100.459	00 199
HF	1	20.0064	30 117
HI	1	127.9124	10 691
HIO_3	1	175.9106	24 529
HNO_3	1	63.0129	79 943
H_3PO_4 (with methyl orange, or methyl yellow, or bromocresol blue)	1	97.9953	99 121
H_3PO_4 (with thymolphthalein, or phenolphthalein, or thymol blue in the presence of NaCl)	1/2	48.9977	69 018
H_3PO_4 (with phenolphthalein in the presence of $CaCl_2$)	1/3	32.6651	51 408
H_3PO_4 (titration of phosphoromolybdate precipitate)	1/23	4.2607	62 948
H_2SO_4	1/2	49.039	69 054
K_2CO_3 (with thymol blue or phenolphthalein)	1	138.213	14 055
K_2CO_3 (with methyl yellow, or methyl orange, or bromophenol blue, or bromocresol blue)	1/2	69.107	83 952
$KHCO_3$	1	100.119	00 052

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
$KHC_4H_4O_6$ (hydrotartrate)	1	188.183	27 458
$KHC_8H_4O_4$ (hydrophthalate)	1	204.229	31 012
$KH(IO_3)_2$	1	389.915	59 097
KOH	1	54.109	74 903
Li_2CO_3 (with thymol blue or phenolphthalein)	1	73.887	86 857
Li_2CO_3 (with methyl yellow, or methyl orange, or bromophenol blue, or bromocresol blue)	1/2	36.944	56 754
$MgCO_3$	1/2	42.157	62 487
MgO	1/2	20.152	30 432
N (according to Kjeldahl)	1	14.0067	14 634
6.25 N ("albumen")	—	87.5419	94 222
6.37 N ("casein")	—	89.2227	95 048
5.55 N ("gelatin")	—	77.7372	89 063
NH_3	1	17.0306	23 123
NH_4^+	1	18.0386	25 620
NH_4Cl	1	53.492	72 829
$(NH_4)_2SO_4$	1/2	66.070	82 000
Na [titration with alkali and phenolphthalein of precipitate $NaZn(UO_2)_3(C_2H_3O_2)_9 \cdot 6H_2O$]	1/10	2.29898	36 154
$Na_2B_4O_7 \cdot 10H_2O$	1/2	190.69	28 033
Na_2CO_3 (with thymol blue or phenolphthalein)	1	105.9890	02 526
Na_2CO_3 (with methyl yellow, or methyl orange, or bromophenol blue, or bromocresol blue)	1/2	52.9945	72 423
$Na_2CO_3 \cdot 10H_2O$	1/2	143.071	15 555
$NaHCO_3$	1	84.0071	92 432
NaOH	1	39.9972	60 203
P (titration of phosphoromolybdate precipitate)	1/23	1.3467	12 927
PO_4^{3-} (titration of phosphoromolybdate precipitate)	1/23	4.1292	61 587

B. Oxidation-Reduction Methods (Manganatometry, Chromatometry, Iodometry, Bromatometry, Ceriometry, etc.)

Substances used for titration and the concentrations of their normal solutions:

(a) *Oxidizing Agents*

Formula	$KMnO_4$	$Co(NH_4)_4(SO_4)_4 \cdot 2H_2O$	$Co(SO_4)_2 \cdot 4H_2O$
Concentration of 1N solution (g/l) . . .	31.6075	632.55	404.30

Table 14 (continued)

Formula	I_2	$KBrO_3$	$K_2Cr_2O_7$
Concentration of 1*N* solution (g/l)	126.9044	27.835	49.032
Formula	KIO_3	$Ca(ClO)_2$	NH_4VO_3
Concentration of 1*N* solution (g/l)	35.6674	35.745	116.979

(b) *Reducing Agents*

Formula	$Na_2S_2O_3 \cdot 5H_2O$	$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	$FeSO_4 \cdot 7H_2O$
Concentration of 1*N* solution (g/l)	248.18	392.14	278.02
Formula	$C_6H_8O_6$ (ascorbic acid)	$Hg_2(NO_3)_2 \cdot 2H_2O$	
Concentration of 1*N* solution (g/l)	88.064	280.61	

Substance being determined	$\frac{E}{M}$	Equivalent weight, *E*	log *E*
Al (after precipitation with hydroxyquinoline)	1/12	2.24846	35 189
As ($As^{3+} \rightleftarrows As^{5+}$)	1/2	37.46080	57 358
Ba (after precipitation in the form of $BaCrO_4$)	1/3	45.780	66 068
Bi (after precipitation with hydroxyquinoline)	1/12	17.4150	24 092
Br	1	79.904	90 257
BrO_3^-	1/6	21.3170	32 873
C_6H_5OH (according to Koppeshaar) (phenol)	1/6	15.6857	19 550
CN^- (iodometrically and according to Schulek)	1/2	13.00895	11 424
Ca (after precipitation in the form of CaC_2O_4)	1/2	20.040	30 190
Cd (after precipitation with hydroxyquinoline)	1/8	14.050	14 768
Ce (after precipitation with hydroxyquinoline)	1/12	11.677	06 733
Cl (active)	1	35.453	54 965
Cl_2	1/2	35.453	54 965
ClO^-	1/2	25.726	41 037
ClO_3^-	1/6	13.9035	14 312
Co [after precipitation in the form of $K_3Co(NO_2)_6$]	1/11	5.3576	72 897

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, *E*	log *E*
Co (after precipitation with hydroxyquinoline)	1/8	7.3667	86 727
Cr ($Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$)	1/3	17.3320	23 885
CrO_4^{2-}	1/3	38.6647	58 731
$Cr_2O_7^{2-}$	1/6	35.9980	55 628
Cu (iodometrically)	1	63.546	80 309
Cu (titration of precipitate CuSCN with permanganate)	1/6	10.5910	02 494
Cu (after precipitation with hydroxyquinoline)	1/8	7.9433	90 000
Fe ($Fe^{3+} \rightleftarrows Fe^{2+}$)	1	55.847	74 700
Fe (after precipitation with hydroxyquinoline)	1/12	4.6539	66 782
$Fe(CN)_6[Fe(CN)_6^{3-} \rightarrow Fe(CN)_6^{4-}]$	1	211.954	32 624
$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	1	392.14	59 344
FeO	1	71.846	85 640
Fe_2O_3	1/2	79.846	90 225
$FeSO_4$	1	151.91	18 159
$FeSO_4 \cdot 7H_2O$	1	278.02	44 408
Ga (after precipitation with hydroxyquinoline)	1/12	5.810	76 418
HCN (iodometrically and according to Schulek)	1/2	13.5129	13 075
$H_2C_2O_4$ (oxalic)	1/2	45.0180	65 339
$H_2C_2O_4 \cdot 2H_2O$	1/2	63.0333	79 957
HI	1	127.9124	10 691
HNO_2	1/2	23.5068	37 119
H_2O_2	1/2	17.0074	23 064
H_2S (iodometrically)	1/2	17.040	23 147
H_2S (bromatometrically and manganatometrically)	1/8	4.2600	62 941
HSCN (manganatometrically)	1/6	9.8483	99 336
HSCN (iodometrically according to Rupp and Schied)	1/8	7.3863	86 843
H_2SO_3	1/2	41.039	61 320
H_2SO_4 (through barium chromate)	1/3	32.693	51 445
I	1	126.9044	10 348
I^- (after oxidation to iodine with a nitrite)	1	126.9044	10 348
I^- (after oxidation to IO_3^- with bromine)	1/6	21.1507	32 533
IO_3^-	1/6	29.1504	46 464
In (after precipitation with hydroxyquinoline)	1/12	9.5682	98 083

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
$KBrO_3$	1/6	27.834	44 458
$KClO_3$	1/6	20.426	31 018
K_2CrO_4	1/3	64.733	81 113
$K_2Cr_2O_7$	1/6	49.032	69 048
$K_3Fe(CN)_6$	1	329.26	51 754
$K_4Fe(CN)_6$	1	368.36	56 627
$K_4Fe(CN)_6 \cdot 3H_2O$	1	422.41	62 573
$KH(IO_3)_2$	1/12	32.4929	51 179
KIO_3	1/6	35.6674	55 227
$KMnO_4$	1/5	31.6075	49 979
KNO_2	1/2	42.554	62 894
Mg (after precipitation with hydroxyquinoline)	1/8	3.0381	48 260
Mn (by the bismuthate method)	1/5	10.9876	04 090
Mn (by Volhard's method)	3/10	16.4814	21 699
Mn (by Ford-William's or Hampe's method)	1/2	27.4690	43 884
Mn (after precipitation with hydroxyquinoline)	1/8	6.5782	81 811
MnO_2 (treatment with $FeSO_4$-$KMnO_4$)	1/2	43.4685	63 817
Mo (iodometrically)	1	95.94	98 200
Mo (after reduction with zinc)	1/3	31.980	50 488
Mo (after precipitation with hydroxyquinoline)	1/8	11.993	07 893
NH_2OH	1/2	16.5131	21 783
NO_2^-	1/2	23.0028	36 178
Na [dissolution of precipitate $NaZn(UO_2)_3 \cdot (C_2H_3O_2)_9 \cdot 6H_2O$, reduction with zinc and titration]	1/6	3.8316	58 338
$Na_2C_2O_4$	1/2	67.000	82 607
$NaClO$	1/2	37.221	57 079
$NaNO_2$	1/2	34.4977	53 779
Na_2S ($S^{2-} \rightarrow S^0$)	1/2	39.022	59 131
Na_2SO_3	1/2	63.021	79 949
$Na_2S_2O_3$	1	158.11	19 896
$Na_2S_2O_3 \cdot 5H_2O$	1	248.18	39 477
Nb	1/2	46.453	66 701
Nb (empirically)	—	49.9	69 810
Ni (after precipitation with hydroxyquinoline)	1/8	7.339	86 564
O ("activated oxygen")	1/2	7.9997	90 307
O_3	1/2	23.9991	38 019
P (titration of phosphoromolybdate precipitate with permanganate after reduction with zinc)	1/36	0.8638	93 469

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
Pb (after precipitation of PbC_2O_4)	1/2	103.595	01 534
Pb (after precipitation of $PbCrO_4$)	1/3	69.063	83 925
Pb (after precipitation with hydroxyquinoline)	1/8	25.899	41 328
S ($S^{2-} \rightarrow S^0$)	1/2	16.032	20 499
S ($S^{2-} \rightarrow SO_4^{2-}$)	1/8	4.008	60 293
SCN^- (manganatometrically) . .	1/6	9.6803	98 589
SCN^- (iodometrically according to Rupp and Schied)	1/8	7.2603	86 095
SO_2	1/2	32.032	50 558
SO_3^{2-}	1/2	40.031	60 240
SO_4^{2-} (through barium chromate)	1/3	32.021	50 543
$S_2O_3^{2-}$ ($2S_2O_3^{2-} \rightarrow S_4O_6^{2-}$)	1	112.13	04 972
$S_2O_3^{2-}$ ($S_2O_3^{2-} \rightarrow 2SO_4^{2-}$)	1/8	14.016	14 662
Sb ($Sb^{3+} \rightarrow Sb^{5+}$)	1/2	60.875	78 444
Sb (after precipitation with hydroxyquinoline)	1/12	10.146	00 629
Sn ($Sn^{2+} \rightarrow Sn^{4+}$)	1/2	59.345	77 338
Th (after precipitation with hydroxyquinoline)	1/16	14.502	16 143
Ti	1	47.90	68 034
Ti (after precipitation with hydroxyquinoline)	1/8	5.988	77 728
U ($U^{4-} \rightarrow UO_2^{2+}$)	1/2	119.015	07 560
U (after precipitation with hydroxyquinoline)	1/12	19.836	29 745
V ($VO^{2+} \rightarrow VO_3^-$)	1	50.942	70 708
V (after precipitation with hydroxyquinoline)	1/8	6.368	80 400
Zn (after precipitation with hydroxyquinoline)	1/8	8.171	91 228
Zr (after precipitation with hydroxyquinoline)	1/16	5.701	75 595

C. Methods of Precipitation and Complexing*

Substances used for titration and the concentrations of their normal solutions:

Formula	$AgNO_3$	$Hg(NO_3)_2 \cdot H_2O$	KSCN	NaCl
Concentration of 1N solution (g/l) . .	169.873	171.31	97.184	58.443
Formula	NH_4SCN	$Hg_2(NO_3)_2 \cdot 2H_2O$		K_2CrO_4
Concentration of 1N solution (g/l) . .	76.120	280.61		97.099

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* For methods of titration with complexone III, see section D, p. 130.

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
Ag	1	107.868	03 289
$AgNO_3$	1	169.873	23 012
Ba (direct titration of K_2CrO_4)	1/2	68.670	83 677
Br^-	1	79.904	90 257
CN^- (according to Mohr, Volhard, Fajans)	1	26.0179	41 527
CN^- (according to Liebig, Denigès)	2	52.0357	71 630
Cl^-	1	35.453	54 965
F^- (after precipitation in the form of PbClF)	1	18.9984	27 872
HBr	1	80.912	90 801
HCN (according to Mohr, Volhard, Fajans)	1	27.0258	43 178
HCN (according to Liebig, Denigès)	2	54.0516	73 281
HCl	1	36.461	56 183
HI	1	127.9124	10 691
HSCN (according to Volhard)	1	59.090	77 151
Hg (with rhodanide)	1/2	100.295	00 128
I	1	126.9044	10 348
KBr	1	119.006	07 557
KCN (according to Mohr, Volhard, Fajans)	1	65.120	81 371
KCN (according to Liebig, Denigès)	2	130.240	11 474
KCl	1	74.555	87 248
KI	1	166.006	22 012
NH_4Cl	1	53.492	72 829
NaBr	1	102.894	01 239
NaCl	1	58.443	76 673
NaI	1	149.8942	17 578
SCN^- (according to Volhard)	1	58.082	76 404

D. Methods of Titration with Complexone III

(with sodium ethylenediaminetetraacetate, EDTA, trilon B)

Substances used for titration and the concentrations of their normal (molar) solutions:

Formula	$Na_2H_2C_{10}H_{12}O_8N_2$	$Na_2H_2C_{10}H_{12}O_8N_2 \cdot 2H_2O$
Concentration of 1N (1M) solution (g/l)	336.211	372.242

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
Ag [after adding $K_2Ni(CN)_4$]	2	215.736	33 392
Al	1	26.9815	43 106

Table 14 (continued)

Substance being determined	$\frac{E}{M}$	Equivalent weight, E	log E
As (in the form of $MgNH_4AsO_4$)	1	74.9216	87 461
AsO_4^{3-} (in the form of $MgNH_4AsO_4$)	1	138.9192	14 276
Ba	1	137.34	13 780
Bi	1	208.980	32 010
Br (through AgBr)	2	159.808	20 360
CN^- (after adding Ni^{2+} salt)	4	104.0714	01 733
Ca	1	40.08	60 293
Cd	1	112.40	05 077
Ce	1	140.12	14 650
Cl (through AgCl)	2	70.906	85 068
Co	1	58.9332	77 036
Cr	1	51.996	71 597
Cu	1	63.546	80 309
F (after adding Ca^{2+} salt)	2	37.9968	57 974
F (through PbClF)	1	18.9984	27 872
Fe	1	55.847	74 700
Ga	1	69.72	84 336
Hg	1	200.59	30 231
I (through AgI)	2	253.8088	40 451
In	1	114.82	06 002
Ir	1	192.2	28 375
K [in the form of $NaK_2Co(NO_2)_6$]	2	78.204	89 323
La	1	138.91	14 273
Mg	1	24.305	38 570
Mn	1	54.9381	73 987
Mo (in the form of $CaMoO_4$)	1	95.94	98 200
Na [in the form of $NaZn(UO_2)\cdot(C_2H_3O_2)_9\cdot6H_2O$]	1	22.9898	36 154
Ni	1	58.71	76 871
P (in the form of $MgNH_4PO_4$)	1	30.9738	49 099
PO_4^{3-} (in the form of $MgNH_4PO_4$)	1	94.9714	97 759
Pb	1	207.19	31 637
Pd [after adding $K_2Ni(CN)_4$]	1	106.4	02 694
Pt [after adding $K_2Ni(CN)_4$]	1	195.09	29 024
S (in the form of $BaSO_4$)	1	32.064	50 602
SCN^- (through AgSCN)	2	116.16	06 506
SO_4^{2-} (in the form of $BaSO_4$)	1	96.062	98 255
Sn(II)	1	118.69	07 441
Sr	1	87.62	94 260
Th	1	232.038	36 556
Ti	1	47.90	68 034
Tl	1	204.37	31 042
U	2	476.06	67 766
V(IV)	1	50.942	70 708
W (in the form of $CaWO_4$)	1	183.85	26 446
Zn	1	65.37	81 538
Zr	1	91.22	96 009

Table 15

Masking Reagents in Titration with Complexone III

Masking reagent	pH	Indicator (or method)	Ions being masked	Ions being titrated
Ascorbic acid	2.5	Pyrocatechol violet	Cu^{2+}, Hg^{2+}, Fe^{3+}	Bi^{3+}, Th^{IV}
Ascorbic acid + + KCN	10	Eriochrome Black T	Fe^{3+} and all ions being masked by KCN	Mn^{2+}, Pb^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}
Ascorbic acid + KI or ascorbic acid + KSCN	5-6	PAN*	Cu^{2+}, Hg^{2+}	Zn^{2+}
Citrate-ion	5-6	PAN*	UO_2^{2+}, Th^{IV}, Zr^{IV}, Sn^{2+}	Zn^{2+}
Citrate-ion	7	Potentiometric-ally	UO_2^{2+}, Th^{IV}, Zr^{IV}, Sb^{3+}, Ti^{IV}, Nb^{V}, Ta^{V}, Mo^{VI}, W^{VI}, Be^{2+}, Fe^{3+}, Cr^{3+}	Cd^{2+}, Cu^{2+}, Hg^{2+}, Pb^{2+}, Zn^{2+}, Y^{3+}
Cyanide-ion	10	Eriochrome Black T	Cu^{2+}, Co^{2+}, Hg^{2+}, Ni^{2+}, Zn^{2+}, Cd^{2+}, Pt^{2+}, Pd^{2+}, Ag^{+}, Tl^{3+}. The addition of formaldehyde or chloral hydrate demasks Cd^{2+} and Zn^{2+}	Ca^{2+}, Mg^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}, Mn^{2+}, In^{3+} (RE^{3+})**, Ga^{3+}

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* PAN: 1-(2-pyridyl-azo)-2-naphthol.

** RE: rare-earth elements (lanthanoids, Y and Sc).

Table 15 (continued)

Masking reagent	pH	Indicator (or method)	Ions being masked	Ions being titrated
Diethyl dithiocarbamate	10	Eriochrome Black T	Hg^{2+}, Pb^{2+}, Cu^{2+}, Pd^{2+}, Bi^{3+}	Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}
2,3-Dimercaptopropanol (dimercaprol, dicaptol, BAL)	10	Eriochrome Black T	Hg^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+}, Bi^{3+}, Ag^{+}, As^{3+}, Sb^{3+}, Sn^{IV} (Cu^{2+}, Co^{2+}, Ni^{2+}, Mn^{3+} and Fe^{3+} only in small quantities, since their complexes with the masking reagent are strongly coloured)	Ca^{3+}, Mg^{2+}, Sr^{2+}, Ba^{2+} (and Mn^{2+}, in the presence of hydroxylamine and triethanolamine)
Fluoride-ion	6	PAN*	Be^{2+}, Nb^{V}, Ta^{V}, Ti^{IV}	Cu^{2+}, Zn^{2+}
Fluoride-ion	6	Pyrocatechol violet	Al^{3+}, Ti^{IV}	Cu^{2+} (Fe^{3+} by back titration)
Fluoride-ion	10	Eriochrome Black T	Al^{3+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+} (RE^{3+})**	Zn^{2+}, Cd^{2+}, Mn^{2+} (Ni^{2+} and Co^{2+} by back titration)
Formic acid or formaldehyde	2.5	Pyrocatechol violet	Hg^{2+}	Bi^{3+}, Th^{IV}

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* PAN: 1-(2-pyridyl-azo)-2-naphthol.

** RE: rare-earth elements (lanthanoids, Y and Sc).

Table 15 (continued)

Masking reagent	pH	Indicator (or method)	Ions being masked	Ions being titrated
Hydrogen peroxide	10	Eriochrome Black T	Ti^{IV}, UO_2^{2+}	Zn^{2+}, Mg^{2+}
Iodide-ion	5-6	PAN*	Hg^{2+}, Cu^{2+}, Tl^{3+}	Zn^{2+}
Oxalate-ion	2	Pyrocatechol violet	Sn^{2+}, (RE^{3+})**	Bi^{3+}
Pentandion-2,4	7	Potentiometric-ally	Al^{3+}, UO_2^{2+}	La^{3+}, (RE^{3+})**, Zn^{2+}
Pentandion-2,4 + + citrate-ion	7	Potentiometric-ally	Al^{3+}, Th^{IV}	Zn^{2+}
Sulphosalicylic acid	4.5	Potentiometric-ally	UO_2^{2+}, Al^{3+}	(RE^{3+})**, Y^{3+}, Th^{IV}
Tartrate-ion	5-6	PAN*	UO_2^{2+}, Sb^{3+}	Zn^{2+}, Cd^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, (RE^{3+})**

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* PAN: 1-(2-pyridyl-azo)-2-naphthol.

** RE: rare-earth elements (lanthanoids, Y and Sc).

Table 15 (continued)

Masking reagent	pH	Indicator (or method)	Ions being masked	Ions being titrated
Tartrate-ion	7	Potentiometrically	Mo^{IV}, Nb^{V}, Sb^{3+}, W^{VI}, UO_2^{2+}	Zn^{2+}, Cd^{2+}, Cu^{2+}, Hg^{2+}, Pb^{2+}
Thiomalate	3	Pyrocatechol violet	Fe^{3+}, Bi^{3+}	Th^{IV}
Thiourea	5-6	PAN*	Cu^{2+}, Hg^{2+}	Zn^{2+}
Thiosemicarbazide	5	PAN*	Cu^{2+}, Hg^{2+}	Zn^{2+}, Cd^{2+}, Pb^{2+}
Thiosulphate-ion	6	PAN*	Cu^{2+}	Zn^{2+}, Cd^{2+}, Ni^{2+}
Triethanolamine	10	Eriochrome Black T	Al^{3+}, Fe^{3+}, Sn^{IV}	Mg^{2+}, Zn^{2+}, Cd^{2+} [Mn^{2+} in the presence of ascorbic acid, Pb^{2+} and (RE^{2+})**]
	11-12	Murexide	Al^{3+}, Fe^{3+}, (Mn^{III})	Ca^{2+}, Ni^{2+}
Unithiol (sodium 2,3-dimercaptopropansulphonate)	10-11	Eriochrome Black T	Zn^{2+}, Cd^{2+}, Hg^{2+}, Pb^{2+}, Sn^{2+}, Sn^{IV}, As^{III}, As^{V}, Sb^{III}, Sb^{V}, Bi^{3+}, Ag^{+}	Ca^{2+}, Mg^{2+}, Sr^{2+}, Ba^{2+}

---

* PAN: 1-(2-pyridyl-azo)-2-naphthol.

** RE: rare-earth elements (lanthanoids, Y and Sc).

Table 16

Calculation of the Results of Gas and Gasometric Analyses*

If an analysis of a substance is reduced to the preparation of a certain gas whose volume is measured, then, for further estimates, this volume must be brought to standard conditions, i.e., to a temperature of 0 °C and a pressure of 760 mm Hg.

Here, three cases are possible:

1. Gas collected dry over mercury

In this case the gas volume under standard conditions (V_0) is found by the approximate but sufficiently accurate formula:

$$V_0 = V\frac{P_0}{(1+\alpha t)\,760} = V$$

where V = measured gas volume;
t = gas temperature;
α = 0.003670;
P_0 = barometer reading brought to 0 °C.

$$F = \frac{P_0}{(1+\alpha t)\,760}$$

Value P_0 is found by the formula:

$$P_0 = \left(P_t - \frac{1}{8}t'\right) \text{ mm Hg}$$

where P_t = barometer reading;
t' = temperature of mercury in the barometer (the temperature of the air around the barometer is measured).

$$\log V_0 = \log V + \log F$$

The values of log F for various values of t and P_0 are given in Table 16,A.

2. Gas collected over water

In this case a correction for mercury temperature must be made in the barometer reading and water vapour pressure at temperature t must be deducted:

$$P_0 = P_t - \frac{1}{8}t' - P_B$$

where P_B is the water vapour pressure at the corresponding temperature of gas over water; it is given in section B of this table.

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* For the use of the table, see p. 468.

Table 16 (continued)

3. Gas collected over KOH *solution or over a saturated* NaCl *solution*

In this case the value of water vapour pressure over the corresponding absorbing aqueous solution must be deducted from the value of P_t:

$$P_0 = P_t - \frac{1}{8}t' - P_B$$

The values of P_B for aqueous solutions are given in Table 16,B.

If the collected gas is the component whose content is determined in the substance being analysed, then, to find the mass of this gas, the found volume V_0 must obviously be multiplied by the density ρ of this gas under standard conditions; hence, the percentage (x) of the unknown component is:

$$x = \frac{V_0 \times \rho \times 100}{g}$$

where g is the weighed portion of the substance being analysed.

The corresponding values of the mass of one litre of gas in grams or of one millilitre of gas in milligrams and their logarithms are given in Table 16,B.

But if, according to the mass of collected gas, a calculation is made of the percentage of a certain component of a substance which is being analysed and from which this gas is separated, then the mass found must be multiplied by the value of f'. Table 16,D gives the values of f', which are the product of the conversion factor and gas density.

The conversion factor is estimated on the basis of the reaction as a result of which the gas being measured is obtained. Thus, in determining Al according to the amount of liberated H_2, we find that three H atoms are formed per Al atom:

$$f' = \frac{a_{\mathrm{Al}}}{(3a_{\mathrm{H}})(\rho_{\mathrm{H}})} + \frac{a_{\mathrm{Al}}\rho_{\mathrm{H}}}{3a_{\mathrm{H}}} = \frac{26.982 \times 0.08988}{3 \times 1.0080} = 0.8020$$

where a_{Al} = atomic weight of Al;
a_{H} = atomic weight of H;
ρ_{H} = density of H_2 according to Table 16,C.

Thus, the percentage of the unknown compound (x) is found by the formula:

$$x = \frac{V_0 f' \times 100}{g}$$

or

$$x = \frac{VFf' \times 100}{g}$$

Table 16 (continued)

A. Bringing the Gas Volume to Standard Conditions

Temperature, °C	Corrected barometer reading P_0, mm Hg						
	660	661	662	663	664	665	666
	Logarithm of multiplier F						
5	93 083	93 149	93 214	93 280	93 345	93 410	93 476
6	92 927	92 993	93 058	93 134	93 189	93 254	93 320
7	92 771	92 837	92 903	92 969	93 034	93 099	93 164
8	92 616	92 682	92 748	92 814	92 879	92 944	93 009
9	92 462	92 528	92 593	92 659	92 724	92 789	92 855
10	92 308	92 373	92 439	92 505	92 570	92 635	92 701
11	92 154	92 220	92 286	92 352	92 417	92 482	92 547
12	92 001	92 067	92 133	92 199	92 264	92 329	92 394
13	91 849	91 914	91 980	92 046	92 111	92 176	92 242
14	91 697	91 762	91 828	91 894	91 959	92 024	92 090
15	91 546	91 612	91 677	91 743	91 808	91 873	91 939
16	91 395	91 461	91 526	91 592	91 657	91 722	91 788
17	91 245	91 311	91 376	91 442	91 507	91 572	91 638
18	91 095	91 161	91 226	91 292	91 357	91 422	91 488
19	90 946	91 011	91 077	91 143	91 208	91 273	91 339
20	90 797	90 862	90 928	90 994	91 059	91 124	91 190
21	90 649	90 714	90 780	90 846	90 911	90 976	91 042
22	90 501	90 567	90 632	90 698	90 763	90 828	90 894
23	90 354	90 420	90 485	90 551	90 616	90 681	90 747
24	90 207	90 273	90 338	90 404	90 469	90 534	90 600
25	90 061	90 127	90 192	90 258	90 323	90 388	90 454
26	89 915	89 980	90 046	90 112	90 177	90 242	90 308
27	89 770	89 836	89 901	89 967	90 032	90 097	90 163
28	89 625	89 690	89 756	89 822	89 887	89 952	90 018
29	89 481	89 547	89 612	89 678	89 743	89 808	89 874
30	89 337	89 403	89 469	89 534	89 600	89 665	89 730
31	89 194	89 260	89 326	89 391	89 457	89 522	89 587
32	89 051	89 117	89 183	89 248	89 314	89 379	89 444
33	88 909	88 975	88 041	89 106	89 172	89 237	89 302
34	88 767	88 833	88 899	88 964	89 030	89 095	89 160

Proportional parts	66	154	148	142
1	6.6	15.4	14.8	14.2
2	13.2	30.8	29.6	28.4
3	19.8	46.2	44.4	42.6
4	26.4	61.6	59.2	56.8
5	33.0	77.0	74.0	71.0
6	39.6	92.4	88.8	85.2
7	46.2	107.8	103.6	99.4
8	52.8	123.2	118.4	113.6
9	59.4	138.6	133.2	127.8

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg 667	668	669	670	671	672	673	Proportional parts
	Logarithm of multiplier F							
5	93 541	93 606	93 671	93 736	93 801	93 866	93 931	
6	93 385	93 450	93 515	93 580	93 645	93 710	93 775	
7	93 229	93 294	93 359	93 425	93 490	93 554	93 619	
8	93 074	93 139	93 205	93 270	93 339	93 399	93 464	65 1 6.5 2 13.0 3 19.5 4 26.0 5 32.5 6 39.0 7 45.5 8 52.0 9 58.5
9	92 920	92 985	93 050	93 115	93 180	93 244	93 309	
10	92 766	92 831	92 896	92 961	93 026	93 090	93 155	
11	92 612	92 677	92 742	92 807	92 872	92 937	93 062	
12	92 459	92 524	92 589	92 654	92 719	92 784	92 849	
13	92 307	92 372	92 437	92 502	92 567	92 631	92 696	
14	92 155	92 220	92 285	92 350	92 415	92 479	92 544	
15	92 004	92 069	92 134	92 199	92 264	92 328	92 393	
16	91 854	91 918	91 983	92 048	92 113	92 174	92 242	
17	91 703	91 768	91 833	91 898	91 963	92 027	92 092	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
18	91 553	91 618	91 683	91 748	91 813	91 877	91 942	
19	91 404	91 469	91 533	91 599	91 664	91 728	91 793	
20	91 255	91 320	91 385	91 450	91 515	91 579	91 644	
21	91 107	91 172	91 237	91 302	91 367	91 431	91 496	
22	90 959	91 024	91 089	91 154	91 219	91 283	91 348	
23	90 812	90 877	90 942	91 007	91 072	91 136	91 201	
24	90 665	90 730	90 795	90 860	90 925	90 989	91 054	
25	90 519	90 584	90 649	90 714	90 779	90 843	90 908	
26	90 373	90 438	90 503	90 568	90 633	90 697	90 762	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
27	90 228	90 293	90 358	90 423	90 488	90 552	90 617	
28	90 083	90 148	90 213	90 278	90 343	90 407	90 472	
29	89 939	90 004	90 069	90 134	90 199	90 263	90 328	
30	89 796	89 861	89 926	89 990	90 055	90 120	90 185	
31	89 653	89 718	89 783	89 847	89 912	89 977	90 042	
32	89 510	89 575	89 640	89 704	89 769	89 834	89 899	
33	89 368	89 433	89 498	89 562	89 627	89 692	89 757	
34	89 226	89 291	89 356	89 420	89 485	89 550	89 615	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg						
	674	675	676	677	678	679	680
	Logarithm of multiplier F						
5	93 995	94 060	94 124	94 188	94 252	94 316	94 380
6	93 839	93 904	93 968	94 032	94 096	94 160	94 224
7	93 683	93 748	93 812	93 876	93 940	94 004	94 068
8	93 528	93 593	93 657	93 721	93 785	93 849	93 913
9	93 373	93 438	93 502	93 566	93 630	93 694	93 758
10	93 219	93 284	93 348	93 412	93 476	93 540	93 604
11	93 066	93 131	93 195	93 259	93 323	93 387	93 451
12	92 913	92 978	93 042	93 106	93 170	93 234	93 298
13	92 761	92 826	92 889	92 954	93 018	93 082	93 145
14	92 609	92 674	92 737	92 802	92 866	92 930	92 993
15	92 458	92 522	92 586	92 651	92 715	92 779	92 842
16	92 307	92 371	92 435	92 500	92 564	92 628	92 691
17	92 156	92 221	92 285	92 349	92 413	92 478	92 541
18	92 006	92 071	92 135	92 199	92 263	92 327	92 391
19	91 857	91 922	91 986	92 050	92 114	92 178	92 242
20	91 708	91 773	91 837	91 901	91 965	92 029	92 093
21	91 560	91 625	91 689	91 753	91 817	91 881	91 945
22	91 412	91 477	91 541	91 605	91 669	91 733	91 797
23	91 265	91 330	91 394	91 458	91 522	91 586	91 650
24	91 118	91 183	91 247	91 311	91 375	91 439	91 503
25	90 972	91 037	91 101	91 165	91 229	91 293	91 357
26	90 826	90 891	90 955	91 019	91 083	91 147	91 211
27	90 681	90 746	90 810	90 874	90 938	91 002	91 066
28	90 536	90 601	90 665	90 729	90 793	90 857	90 911
29	90 392	90 457	90 521	90 585	90 649	90 713	90 777
30	90 249	90 313	90 378	90 442	90 506	90 570	90 634
31	90 106	90 170	90 235	90 299	90 363	90 427	90 491
32	89 963	90 027	90 092	90 156	90 220	90 284	90 348
33	89 821	89 885	89 950	90 014	90 078	90 142	90 206
34	89 679	89 743	89 808	89 872	89 936	90 000	90 064

Proportional parts

	64
1	6.4
2	12.8
3	19.2
4	25.6
5	32.0
6	38.4
7	44.8
8	51.2
9	57.6

	154
1	15.4
2	30.8
3	46.2
4	61.6
5	77.0
6	92.4
7	107.8
8	123.2
9	138.6

	148
1	14.8
2	29.9
3	44.4
4	59.2
5	74.0
6	88.8
7	103.6
8	118.4
9	133.2

	142
1	14.2
2	28.4
3	42.6
4	56.8
5	71.0
6	85.2
7	99.4
8	113.2
9	127.8

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	681	682	683	684	685	686	687	
	Logarithm of multiplier F							
5	94 444	94 507	94 571	94 634	94 698	94 761	94 825	
6	94 288	94 351	94 415	94 478	94 544	94 605	94 669	
7	94 132	94 195	94 259	94 323	94 387	94 449	94 513	
8	93 977	94 040	94 104	94 168	94 232	94 294	94 358	63 1 6.3 2 12.6 3 18.9 4 25.2 5 31.5 6 37.8 7 44.1 8 50.4 9 56.7
9	93 822	93 886	93 950	94 013	94 077	94 140	94 203	
10	93 668	93 732	93 796	93 859	93 923	93 986	94 049	
11	93 515	93 578	93 644	93 705	93 769	93 832	93 896	
12	93 362	93 425	93 489	93 552	93 616	93 679	93 743	
13	93 209	93 273	93 337	93 400	93 464	93 527	93 590	
14	93 057	93 121	93 185	93 248	93 312	93 375	93 438	
15	92 906	92 970	93 034	93 097	93 161	93 224	93 287	
16	92 755	92 819	92 883	92 946	93 010	93 073	93 136	
17	92 605	92 669	92 733	92 796	92 860	92 923	92 986	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
18	92 455	92 519	92 583	92 646	92 710	92 773	92 836	
19	92 306	92 370	92 434	92 497	92 561	92 624	92 687	
20	92 157	92 221	92 285	92 348	92 412	92 475	92 538	
21	92 009	92 073	92 137	92 200	92 264	92 327	92 390	
22	91 861	91 925	91 989	92 052	91 116	92 179	92 242	
23	91 714	91 778	91 842	91 905	91 969	92 032	92 095	
24	91 567	91 631	91 695	91 758	91 822	91 885	91 948	
25	91 421	91 485	91 549	91 612	91 676	91 739	91 802	
26	91 275	91 339	91 403	91 466	91 530	91 593	91 656	
27	91 130	91 194	91 258	91 321	91 385	91 448	91 511	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
28	90 975	91 049	91 113	91 176	91 240	91 303	91 366	
29	90 841	90 905	90 969	91 032	91 096	91 159	91 222	
30	90 698	90 761	90 825	90 889	90 952	91 015	91 079	
31	90 555	90 618	90 682	90 746	90 809	90 872	90 936	
32	90 412	90 475	90 539	90 603	90 666	90 729	90 793	
33	90 270	90 333	90 397	90 461	90 524	90 587	90 651	
34	90 128	90 191	90 255	90 319	90 382	90 445	90 509	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	688	689	690	691	692	693	694	
	Logarithm of multiplier F							
5	94 888	94 951	95 014	95 077	95 139	95 202	95 265	63 1 6.3 2 12.6 3 18.9 4 25.2 5 31.5 6 37.8 7 44.1 8 50.4 9 56.7
6	94 732	94 795	94 858	94 921	94 983	95 046	95 109	
7	94 576	94 639	94 702	94 765	94 828	94 891	94 953	
8	94 421	94 484	94 547	94 610	94 673	94 736	94 798	
9	94 266	94 329	94 392	94 455	94 518	94 581	94 643	
10	94 112	94 175	94 238	94 301	94 364	94 427	94 489	
11	93 959	94 022	94 085	94 148	94 210	94 273	94 336	
12	93 806	93 869	93 932	93 995	94 057	94 120	94 183	
13	93 653	93 719	93 779	93 842	93 905	93 968	94 030	
14	93 501	93 564	93 627	93 690	93 753	93 816	93 878	154 1 15.4 2 30.8 3 46.2 4 61.6 5 77.0 6 92.4 7 107.6 8 123.2 9 138.6
15	93 350	93 413	93 476	93 539	93 602	93 665	93 727	
16	93 199	93 262	93 325	93 389	93 451	93 514	93 576	
17	93 049	93 112	93 175	93 228	93 301	93 364	93 426	
18	92 899	92 962	93 025	93 088	93 151	93 214	93 276	
19	92 750	92 813	92 876	92 939	93 002	93 065	93 127	
20	92 601	92 664	92 727	92 790	92 853	92 916	92 979	148 1 14.8 2 29.6 3 44.4 4 59.2 5 74.0 6 88.8 7 101.6 8 118.5 9 133.2
21	92 453	92 516	92 579	92 642	92 705	92 768	92 830	
22	92 305	92 368	92 431	92 494	92 557	92 620	92 682	
23	92 158	92 221	92 284	92 347	92 410	92 473	92 535	
24	92 011	92 074	92 137	92 200	92 263	92 326	92 388	
25	91 865	91 928	91 991	92 054	92 117	92 180	92 242	
26	91 719	91 782	91 845	91 908	91 971	92 034	92 096	
27	91 574	91 637	91 700	91 763	91 826	91 889	91 951	
28	91 429	91 492	91 555	91 618	91 681	91 744	91 806	142 1 14.2 2 28.4 3 42.6 4 56.8 5 71.0 6 85.2 7 99.4 8 113.6 9 127.8
29	91 285	91 348	91 411	91 474	91 537	91 600	91 662	
30	91 142	91 205	91 268	91 331	91 394	91 456	91 519	
31	90 999	91 061	91 125	91 188	91 251	91 313	91 376	
32	90 856	90 919	90 982	91 045	91 108	91 170	91 233	
33	90 714	90 777	90 840	90 903	90 966	91 028	91 091	
34	90 572	90 635	90 698	90 761	90 824	90 886	90 949	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	695	696	697	698	699	700	701	
	Logarithm of multiplier *F*							
5	95 328	95 390	95 452	95 514	95 577	95 639	95 701	
6	95 172	95 234	95 296	95 358	95 421	95 483	95 545	
7	95 015	95 078	95 140	95 203	95 265	95 327	95 389	
8	94 861	94 923	94 986	95 048	95 110	95 172	95 234	62 1 6.2 2 12.4 3 18.6 4 24.8 5 31.0 6 37.2 7 43.4 8 49.6 9 55.8
9	94 706	94 768	94 831	94 893	94 955	95 017	95 079	
10	94 552	94 614	94 677	94 739	94 801	94 863	94 925	
11	94 399	94 461	94 524	94 585	94 648	94 710	94 772	
12	94 246	94 308	94 370	94 432	94 495	94 557	94 619	
13	94 093	94 155	94 218	94 280	94 342	94 404	94 466	
14	93 941	94 003	94 066	94 128	94 190	94 252	94 314	
15	93 790	93 852	93 915	93 977	94 039	94 101	94 163	
16	93 639	93 701	93 764	93 826	93 888	93 950	94 012	
17	93 489	93 551	93 614	93 676	93 738	93 800	93 862	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.4 8 120.8 9 135.9
18	93 339	93 401	93 464	93 526	93 588	93 650	93 712	
19	93 190	93 252	93 315	93 377	93 439	93 501	93 563	
20	93 041	93 103	93 166	93 228	93 290	93 352	93 414	
21	92 893	92 955	93 018	93 080	93 142	93 204	93 266	
22	92 745	92 807	92 870	92 932	92 994	93 056	93 118	
23	92 598	92 660	92 723	92 785	92 847	92 909	92 975	
24	92 451	92 513	92 576	92 638	92 700	92 762	92 824	
25	92 305	92 367	92 430	92 492	92 554	92 616	92 678	
26	92 159	92 221	92 284	92 346	92 408	92 470	92 532	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.0 8 116.0 9 130.5
27	92 014	92 076	92 139	92 201	92 263	92 325	92 387	
28	91 869	91 931	91 994	92 056	92 118	92 180	92 242	
29	91 725	91 787	91 850	91 912	91 974	92 036	92 098	
30	91 581	91 644	91 706	91 769	91 831	91 893	91 955	
31	91 438	91 501	91 563	91 626	91 688	91 750	91 812	
32	91 295	91 358	91 420	91 483	91 545	91 607	91 669	
33	91 153	91 216	91 278	91 341	91 403	91 465	91 527	
34	91 011	91 074	91 136	91 199	91 261	91 323	91 385	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	702	703	704	705	706	707	708	
	Logarithm of multiplier F							
5	95 763	95 825	95 886	95 948	96 009	96 071	96 132	62 1 6.2 2 12.4 3 18.6 4 24.8 5 31.0 6 37.2 7 43.4 8 49.6 9 55.8
6	95 606	95 668	95 730	95 792	95 859	95 915	95 976	
7	95 451	95 513	95 574	95 636	95 698	95 759	95 820	
8	95 296	95 358	95 419	95 481	95 543	95 604	95 665	
9	95 141	95 203	95 265	95 327	95 388	95 450	95 511	
10	94 987	95 049	95 111	95 173	95 234	95 296	95 357	
11	94 834	94 896	94 957	95 019	95 080	95 142	95 203	
12	94 681	94 743	94 804	94 866	94 927	94 989	95 050	
13	94 528	94 590	94 652	94 718	94 775	94 837	94 898	
14	94 376	94 438	94 500	94 562	94 623	94 685	94 746	154 1 15.4 2 30.8 3 46.2 4 61.6 5 77.0 6 92.4 7 107.8 8 123.2 9 138.6
15	94 225	94 287	94 349	94 411	94 472	94 534	94 595	
16	94 074	94 136	94 198	94 260	94 321	94 383	94 444	
17	93 924	93 986	94 048	94 110	94 171	94 233	94 294	
18	93 774	93 836	93 898	93 960	94 021	94 083	94 144	
19	93 625	93 687	93 749	93 811	93 872	93 934	93 995	
20	93 476	93 538	93 600	93 662	93 723	93 785	93 846	148 1 14.8 2 29.6 3 44.4 4 59.2 5 74.0 6 88.8 7 103.6 8 118.4 9 133.2
21	93 328	93 390	93 452	93 514	93 575	93 637	93 698	
22	93 180	93 242	93 304	93 366	93 427	93 489	93 550	
23	93 033	93 095	93 157	93 219	93 280	93 342	93 403	
24	92 886	92 948	93 010	93 072	93 133	93 195	93 256	
25	92 740	92 802	92 864	92 926	92 987	93 049	93 110	
26	92 594	92 656	92 718	92 780	92 841	92 903	92 964	
27	92 449	92 511	92 573	92 635	92 696	92 759	92 819	
28	92 304	92 366	92 428	92 490	92 551	92 613	92 674	142 1 14.2 2 28.4 3 42.6 4 56.8 5 71.0 6 85.2 7 99.4 8 113.6 9 127.8
29	92 160	92 222	92 284	92 346	92 407	92 469	92 530	
30	92 017	92 079	92 140	92 202	92 263	92 325	92 386	
31	91 874	91 936	91 997	92 059	92 120	92 182	92 243	
32	91 731	91 793	91 854	91 916	91 977	92 039	92 100	
33	91 589	91 651	91 712	91 774	91 835	91 897	91 958	
34	91 447	91 509	91 570	91 632	91 693	91 755	91 816	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	709	710	711	712	713	714	715	
	Logarithm of multiplier F							
5	96 194	96 255	96 316	96 377	96 438	96 499	96 560	
6	96 038	96 099	96 160	96 221	96 282	96 343	96 404	
7	95 882	95 943	96 004	96 065	96 126	96 187	96 248	
8	95 727	95 788	95 849	95 910	95 971	96 032	96 093	61 1 6.1 2 12.2 3 18.3 4 24.4 5 30.5 6 36.6 7 42.7 8 48.8 9 54.9
9	95 572	95 633	95 694	95 755	95 816	95 877	95 938	
10	95 418	95 479	95 540	95 601	95 662	95 723	95 784	
11	95 265	95 326	95 387	95 448	95 509	95 570	95 631	
12	95 112	95 173	95 234	95 295	95 356	95 417	95 478	
13	94 959	95 020	95 082	95 143	95 204	95 264	95 325	
14	94 807	94 868	94 930	94 991	95 052	95 112	95 173	
15	94 656	94 717	94 778	94 839	94 900	94 961	95 022	
16	94 505	94 566	94 627	94 688	94 749	94 810	94 871	
17	94 355	94 416	94 478	94 538	94 599	94 660	94 721	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
18	94 205	94 266	94 327	94 388	94 449	94 510	94 571	
19	94 056	94 117	94 178	94 239	94 300	94 361	94 422	
20	93 907	93 968	94 029	94 090	94 151	94 212	94 273	
21	93 759	93 820	93 881	93 942	94 003	94 064	94 125	
22	93 611	93 672	93 734	93 795	93 856	93 916	93 977	
23	93 464	93 525	93 586	93 648	93 709	93 769	93 830	
24	93 317	93 378	93 440	93 501	93 562	93 622	93 683	
25	93 171	93 232	93 294	93 355	93 416	93 476	93 537	
26	93 025	93 086	93 148	93 209	93 270	93 330	93 391	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
27	92 880	92 941	93 003	93 064	93 125	93 185	93 246	
28	92 735	92 796	92 858	92 919	92 980	93 040	93 101	
29	92 591	92 652	92 713	92 774	92 835	92 896	92 957	
30	92 448	92 509	92 570	92 631	92 692	92 753	92 814	
31	92 305	92 366	92 427	92 488	92 549	92 610	92 671	
32	92 162	92 223	92 284	92 345	92 406	92 467	92 528	
33	92 020	92 081	92 142	92 203	92 264	92 325	92 386	
34	91 878	91 939	92 000	92 061	92 122	92 183	92 244	

Table 16 (*continued*)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	716	717	718	719	720	721	722	
	Logarithm of multiplier F							
5	96 620	96 680	96 741	96 802	96 862	96 922	96 983	61 1 6.1 2 12.2 3 18.3 4 24.4 5 30.5 6 36.6 7 42.7 8 48.8 9 54.9
6	96 464	96 525	96 585	96 646	96 706	96 767	96 827	
7	96 308	96 369	96 429	96 490	96 500	96 611	96 671	
8	96 153	96 214	96 274	96 335	96 395	96 456	96 516	
9	95 999	96 060	96 120	96 181	96 241	96 301	96 361	
10	95 845	95 906	95 966	96 027	96 087	96 147	96 207	
11	95 691	95 752	95 812	95 873	95 933	95 994	96 054	
12	95 538	95 599	95 659	95 720	95 780	95 841	95 901	
13	95 386	95 447	95 507	95 568	95 628	95 688	95 748	
14	95 234	95 295	95 355	95 416	95 476	95 536	95 596	154 1 15.4 2 30.8 3 46.2 4 61.6 5 77.0 6 92.4 7 107.8 8 123.2 9 138.6
15	95 083	95 144	95 204	95 265	95 325	95 385	95 445	
16	94 932	94 993	95 053	95 114	95 174	95 234	95 394	
17	94 782	94 843	94 903	94 964	95 024	95 084	95 144	
18	94 632	94 693	94 753	94 814	94 874	94 934	94 994	
19	94 483	94 544	94 604	94 665	94 725	94 785	94 845	
20	94 334	94 395	94 455	94 516	94 576	94 636	94 696	148 1 14.8 2 29.6 3 44.4 4 59.2 5 74.0 6 88.8 7 103.6 8 118.4 9 133.2
21	94 186	94 247	94 307	94 368	94 428	94 488	94 548	
22	94 038	94 099	94 159	94 220	94 280	94 340	94 400	
23	93 891	93 952	94 012	94 073	94 133	94 193	94 253	
24	93 744	93 805	93 865	93 926	93 986	94 046	94 106	
25	93 598	93 659	93 719	93 780	93 840	93 900	93 960	
26	93 452	93 513	93 573	93 634	93 694	93 754	93 814	
27	93 307	93 368	93 428	93 489	93 549	93 609	93 669	
28	93 162	93 223	93 288	93 344	93 404	93 464	93 524	142 1 14.2 2 28.4 3 42.6 4 56.8 5 71.0 6 85.2 7 99.4 8 113.6 9 127.8
29	93 018	93 079	93 139	93 199	93 259	93 320	93 380	
30	92 874	92 935	92 995	93 056	93 116	93 177	93 237	
31	92 731	92 792	92 852	92 913	92 973	93 034	93 094	
32	92 588	92 649	92 709	92 770	92 830	92 891	92 951	
33	92 446	92 507	92 567	92 628	92 688	92 749	92 809	
34	92 304	92 365	92 425	92 486	92 546	92 607	92 667	

Table 16 (*continued*)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	723	724	725	726	727	728	729	
	Logarithm of multiplier F							
5	97 043	97 103	97 163	97 223	97 283	97 342	97 402	
6	96 887	96 947	97 007	97 067	97 127	97 186	97 246	
7	96 731	96 791	96 851	96 911	96 971	97 030	97 090	
8	96 576	96 636	96 696	96 756	96 816	96 875	96 935	60 1 6.0 2 12.0 3 18.0 4 24.0 5 30.0 6 36.0 7 42.0 8 48.0 9 54.0
9	96 421	96 481	96 541	96 601	96 661	96 721	96 781	
10	96 267	96 327	96 387	96 447	96 507	96 567	96 637	
11	96 114	96 174	96 234	96 294	96 354	96 413	96 473	
12	95 961	96 021	96 081	96 141	96 201	96 260	96 320	
13	95 808	95 868	95 928	95 988	96 048	96 108	96 168	
14	95 656	95 716	95 776	95 836	95 896	95 956	96 016	
15	95 505	95 565	95 625	95 685	95 475	95 805	95 865	
16	95 354	95 414	95 474	95 534	95 594	95 654	95 714	
17	95 204	95 264	95 324	95 384	95 444	95 514	95 564	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
18	95 054	95 114	95 174	95 234	95 294	95 354	95 414	
19	94 905	94 965	95 025	95 085	95 145	95 205	95 265	
20	94 756	94 816	94 876	94 936	94 996	95 056	95 116	
21	94 608	94 668	94 728	94 788	94 848	94 908	94 968	
22	94 460	94 520	94 580	94 640	94 700	94 760	94 820	
23	94 313	94 373	94 433	94 493	94 553	94 613	94 673	
24	94 166	94 226	94 286	94 346	94 406	94 466	94 526	
25	94 020	94 080	94 140	94 200	94 260	94 320	94 380	
26	93 874	93 934	93 994	94 054	94 114	94 174	94 234	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
27	93 729	93 789	93 849	93 909	93 969	94 029	94 089	
28	93 584	93 644	93 704	93 764	93 824	93 885	93 944	
29	93 440	93 500	93 569	93 620	93 680	93 740	93 800	
30	93 297	93 357	93 417	93 477	93 536	93 596	93 656	
31	93 154	93 214	93 274	93 334	93 393	93 453	93 513	
32	93 011	93 071	93 131	93 191	93 250	93 310	93 370	
33	92 869	92 929	92 989	93 049	93 108	93 168	93 228	
34	92 727	92 787	92 847	92 907	92 966	93 026	93 086	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg						
	730	731	732	733	734	735	736
	Logarithm of multiplier F						
5	97 461	97 521	97 580	97 640	97 699	97 758	97 817
6	97 305	97 365	97 424	97 484	97 543	97 602	97 661
7	97 149	97 209	97 268	97 328	97 387	97 446	97 505
8	96 994	97 054	97 113	97 173	97 232	97 291	97 350
9	96 840	96 899	96 958	97 018	97 077	97 136	97 195
10	96 686	96 745	96 804	96 864	96 923	96 982	97 041
11	96 532	96 592	96 651	96 711	96 770	96 829	96 888
12	96 379	96 439	96 498	96 558	96 617	96 676	96 735
13	96 227	96 287	96 346	96 406	96 465	96 524	96 583
14	96 075	96 135	96 194	96 253	96 312	96 371	96 430
15	95 924	95 984	96 043	96 102	96 161	96 220	96 279
16	95 773	95 833	95 892	95 951	96 010	96 069	96 128
17	95 623	95 683	95 742	95 801	95 860	95 919	95 978
18	95 473	95 533	95 592	95 651	95 710	95 769	95 828
19	95 324	95 384	95 443	95 502	95 561	95 620	95 679
20	95 175	95 235	95 294	95 353	95 412	95 471	95 530
21	95 027	95 086	95 145	95 205	95 264	95 323	95 382
22	94 879	94 939	94 998	95 057	95 116	95 175	95 234
23	94 732	94 791	94 850	94 910	94 969	95 028	95 087
24	94 585	94 645	94 704	94 763	94 822	94 881	94 940
25	94 439	94 498	94 557	94 617	94 676	94 735	94 794
26	94 293	94 353	94 412	94 471	94 530	94 589	94 648
27	94 148	94 208	94 267	94 336	94 385	94 444	94 503
28	94 003	94 063	94 122	94 181	94 240	94 299	94 358
29	93 859	93 918	93 977	94 037	94 096	94 155	94 214
30	93 715	93 775	93 834	93 893	93 953	94 012	94 071
31	93 572	93 632	93 691	93 750	93 810	93 869	93 928
32	93 429	93 489	93 548	93 607	93 667	93 726	93 785
33	93 287	93 347	93 406	93 465	93 525	93 584	93 643
34	93 145	93 205	93 264	93 323	93 383	93 442	93 501

Proportional parts				
	59	154	148	142
1	5.9	15.4	14.8	14.2
2	11.8	30.8	29.6	28.4
3	17.7	46.2	44.4	42.6
4	23.6	61.6	59.2	56.8
5	29.5	77.0	74.0	71.0
6	35.4	92.4	88.8	85.2
7	41.3	107.8	103.6	99.4
8	47.2	123.2	118.4	113.6
9	53.1	138.6	133.2	127.8

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	737	738	739	740	741	742	743	
	Logarithm of multiplier F							
5	97 876	97 935	97 994	98 052	98 111	98 170	98 222	
6	97 720	97 779	97 838	97 896	97 955	98 013	98 078	
7	97 564	97 623	97 682	97 740	97 799	97 857	97 916	
8	97 409	97 468	97 527	97 585	97 644	97 702	97 761	59 1 5.9 2 11.8 3 17.7 4 23.6 5 29.5 6 35.4 7 41.3 8 47.2 9 53.1
9	97 254	97 313	97 372	97 431	97 490	97 548	97 607	
10	97 100	97 159	97 218	97 277	97 336	97 394	97 453	
11	96 947	97 006	97 065	97 123	97 182	97 240	97 299	
12	96 794	96 853	96 912	96 970	97 029	97 087	97 146	
13	96 642	96 701	96 760	96 818	96 877	96 935	96 994	
14	96 489	96 548	96 607	96 666	96 725	96 783	96 842	
15	96 338	96 397	96 456	96 515	96 574	96 632	96 691	
16	96 187	96 246	96 305	96 364	96 423	96 481	96 540	
17	96 037	96 096	96 155	96 214	96 273	96 331	96 390	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
18	95 887	95 946	96 005	96 064	96 123	96 181	96 240	
19	95 738	95 797	95 856	95 915	95 974	96 032	96 091	
20	95 589	95 648	95 707	95 766	95 825	95 883	95 942	
21	95 441	95 500	95 559	95 618	95 677	95 735	95 794	
22	95 293	95 352	95 411	95 470	95 529	95 587	95 646	
23	95 146	95 205	95 264	95 323	95 382	95 440	95 499	
24	94 999	95 058	95 117	95 176	95 235	95 293	95 352	
25	94 753	94 912	94 971	95 030	95 089	95 147	95 206	
26	94 707	94 766	94 825	94 884	94 943	95 001	95 060	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
27	94 562	94 621	94 680	94 739	94 798	94 856	94 915	
28	94 417	94 476	94 535	94 594	94 653	94 711	94 770	
29	94 273	94 332	94 391	94 449	94 508	94 567	94 626	
30	94 130	94 189	94 247	94 306	94 365	94 423	94 482	
31	93 987	94 046	94 104	94 163	94 222	94 280	94 339	
32	93 844	93 903	93 961	94 020	94 079	94 137	94 196	
33	93 702	93 761	93 819	93 878	93 937	93 995	94 054	
34	93 560	93 619	93 677	93 736	93 795	93 853	93 912	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg						
	744	745	746	747	748	749	750
	Logarithm of multiplier F						
5	98 286	98 345	98 403	98 461	98 519	98 577	98 635
6	98 130	98 189	98 247	98 305	98 363	98 421	98 479
7	97 974	98 033	98 091	98 149	98 207	98 265	98 323
8	97 819	97 878	97 936	97 994	98 052	98 110	98 168
9	97 665	97 724	97 781	97 839	97 898	97 956	98 013
10	97 511	97 569	97 627	97 686	97 744	97 802	97 859
11	97 357	97 416	97 474	97 532	97 590	97 648	97 706
12	97 204	97 263	97 321	97 379	97 437	97 495	97 553
13	97 052	97 110	97 168	97 227	97 285	97 343	97 401
14	96 900	96 959	97 017	97 075	97 133	97 191	97 249
15	96 749	96 807	96 865	96 924	96 982	97 040	97 098
16	96 598	96 656	96 714	96 773	96 831	96 889	96 947
17	96 448	96 506	96 564	96 622	96 680	96 738	96 796
18	96 298	96 356	96 414	96 472	96 530	96 588	96 646
19	96 149	96 207	96 265	96 323	96 381	96 439	96 497
20	96 000	96 058	96 116	96 174	96 232	96 290	96 348
21	95 852	95 910	95 968	96 026	96 034	96 142	96 200
22	95 705	95 763	95 821	95 879	95 937	95 995	96 053
23	95 558	95 616	95 674	95 732	95 790	95 848	95 906
24	95 411	95 469	95 527	95 585	95 643	95 701	95 759
25	95 264	95 322	95 380	95 439	95 497	95 555	95 613
26	95 118	95 176	95 234	95 293	95 351	95 409	95 467
27	94 973	95 031	95 089	95 148	95 206	95 264	95 322
28	94 828	94 886	94 944	95 003	95 061	95 119	95 177
29	94 684	94 742	94 800	94 858	94 916	94 974	95 032
30	94 540	94 599	94 657	94 715	94 773	94 831	94 889
31	94 397	94 456	94 514	94 572	94 630	94 688	94 746
32	94 254	94 313	94 371	94 429	94 487	94 545	94 603
33	94 112	94 171	94 229	94 287	94 345	94 403	94 461
34	93 970	94 029	94 087	94 145	94 203	94 261	94 319

Proportional parts				
	58	154	148	142
1	5.8	15.4	14.8	14.2
2	11.6	30.8	29.6	28.4
3	17.4	46.2	44.4	42.6
4	23.2	61.6	59.2	56.8
5	29.0	77.0	74.0	71.0
6	34.8	92.7	88.8	85.2
7	40.6	107.0	103.6	99.4
8	46.4	128.2	118.4	113.6
9	52.5	138.6	133.2	127.8

Table 16 (*continued*)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	751	752	753	754	755	756	757	
	Logarithm of multiplier *F*							
5	98 693	98 751	98 809	98 866	98 924	98 981	99 039	
6	98 537	98 595	98 653	98 710	98 768	98 825	98 883	
7	98 381	98 439	98 497	98 554	98 612	98 669	98 727	
8	98 226	98 284	98 342	98 399	98 457	98 514	98 572	58 1 5.8 2 11.6 3 17.4 4 23.2 5 29.0 6 34.8 7 40.6 8 46.4 9 52.2
9	98 071	98 129	98 187	98 244	98 302	98 360	98 417	
10	97 917	97 975	98 033	98 090	98 148	98 206	98 263	
11	97 764	97 822	97 880	97 937	97 995	98 052	98 110	
12	97 611	97 669	97 727	97 784	97 842	97 899	97 957	
13	97 459	97 516	97 574	97 632	97 690	97 747	97 805	
14	97 307	97 364	97 422	97 480	97 538	97 595	97 653	
15	97 156	97 213	97 271	97 329	97 387	97 444	97 501	
16	97 005	97 062	97 120	97 178	97 236	97 293	97 350	
17	96 854	96 912	96 970	97 028	97 086	97 143	97 200	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
18	96 704	96 762	96 820	96 878	96 936	96 993	97 050	
19	96 555	96 613	96 671	96 729	96 787	96 844	96 901	
20	96 406	96 464	96 522	96 580	96 638	96 695	96 752	
21	96 258	96 316	96 374	96 432	96 490	96 547	96 604	
22	96 111	96 168	96 226	96 284	96 342	96 399	96 456	
23	95 964	96 021	96 079	96 137	96 195	96 252	96 309	
24	95 817	95 874	95 932	95 990	96 048	96 105	96 162	
25	95 671	95 728	95 786	95 844	95 902	95 959	96 016	
26	95 525	95 582	95 640	95 698	95 756	95 813	95 870	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
27	95 380	95 437	95 495	95 553	95 611	95 668	95 725	
28	95 235	95 292	95 350	95 408	95 466	95 523	95 580	
29	95 090	95 148	95 206	95 263	95 321	95 378	95 436	
30	94 947	95 005	95 062	95 120	95 178	95 235	95 293	
31	94 804	94 862	94 919	94 977	95 035	95 092	95 150	
32	94 661	94 719	94 776	94 834	94 892	94 949	95 007	
33	94 519	94 577	94 634	94 692	94 750	94 807	94 865	
34	94 377	94 435	94 492	94 550	94 608	94 665	94 723	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg						
	758	759	760	761	762	763	764
	Logarithm of multiplier F						
5	99 096	99 153	99 210	99 267	99 324	99 381	99 438
6	98 940	98 997	99 054	99 111	99 168	99 225	99 282
7	98 784	98 841	98 898	98 956	99 013	99 070	99 126
8	98 629	98 636	98 743	98 801	98 858	98 915	98 971
9	98 474	98 531	98 589	98 646	98 703	98 760	98 817
10	98 320	98 377	98 435	98 492	98 549	98 606	98 663
11	98 167	98 224	98 281	98 338	98 395	98 452	98 509
12	98 014	98 071	98 128	98 185	98 242	98 299	98 356
13	97 862	97 919	97 976	98 033	98 090	98 147	98 204
14	97 710	97 767	97 824	97 881	97 938	97 995	98 052
15	97 558	97 615	97 683	97 730	97 787	97 844	97 901
16	97 407	97 464	97 522	97 579	97 636	97 693	97 750
17	97 257	97 315	97 372	97 429	97 486	97 543	97 600
18	97 107	97 165	97 222	97 279	97 336	97 393	97 450
19	96 958	97 016	97 083	97 130	97 187	97 244	97 301
20	96 809	96 867	96 924	96 981	97 038	97 095	97 152
21	96 661	96 719	96 776	96 833	96 890	96 947	97 004
22	96 513	96 571	96 628	96 685	96 742	96 799	96 856
23	96 366	96 424	96 481	96 538	96 595	96 652	96 709
24	96 219	96 277	96 334	96 391	96 448	96 505	96 562
25	96 073	96 131	96 188	96 245	96 302	96 359	96 416
26	95 927	95 985	96 042	96 099	96 156	96 213	96 270
27	95 782	95 840	95 897	95 954	96 011	96 068	96 125
28	95 637	95 695	95 752	95 809	95 866	95 923	95 980
29	95 493	95 551	95 608	95 665	95 722	95 779	95 836
30	95 350	95 407	95 464	95 521	95 578	95 635	95 692
31	95 207	95 264	95 321	95 378	95 435	95 492	95 549
32	95 064	95 121	95 178	95 235	95 292	95 349	95 406
33	94 922	94 979	95 036	95 093	95 150	95 207	95 264
34	94 780	94 837	94 894	94 951	95 008	95 065	95 122

Proportional parts

	57
1	5.7
2	11.4
3	17.1
4	22.8
5	28.5
6	34.2
7	39.9
8	45.6
9	51.3

	154
1	15.4
2	30.8
3	46.2
4	61.6
5	77.0
6	92.4
7	107.8
8	123.2
9	138.6

	148
1	14.8
2	29.6
3	44.4
4	59.2
5	74.0
6	88.8
7	103.6
8	118.4
9	133.2

	142
1	14.2
2	28.4
3	42.6
4	56.8
5	71.0
6	85.2
7	99.4
8	113.6
9	127.8

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg							Proportional parts
	765	766	767	768	769	770	771	
	Logarithm of multiplier F							
5	99 495	99 552	99 609	99 665	99 722	99 778	99 834	56 1 5.6 2 11.2 3 16.8 4 22.4 5 28.0 6 33.6 7 39.2 8 44.8 9 50.4
6	99 339	99 396	99 453	99 509	99 566	99 622	99 678	
7	99 183	99 240	99 297	99 353	99 410	99 466	99 523	
8	99 028	99 085	99 142	99 198	99 255	99 311	99 368	
9	98 874	98 930	98 987	99 043	99 100	99 156	99 213	
10	98 720	98 776	98 833	98 889	98 946	99 002	99 059	
11	98 566	98 623	98 680	98 736	98 793	98 849	98 906	
12	98 413	98 470	98 527	98 583	98 640	98 696	98 753	
13	98 261	98 317	98 374	98 431	98 488	98 544	98 600	
14	98 109	98 165	98 222	98 279	98 336	98 392	98 448	
15	97 958	98 014	98 071	98 128	98 185	98 241	98 297	151 1 15.1 2 30.2 3 45.3 4 60.4 5 75.5 6 90.6 7 105.7 8 120.8 9 135.9
16	97 807	97 863	97 920	97 977	98 034	98 090	98 146	
17	97 657	97 713	97 770	97 827	97 884	97 940	97 996	
18	97 507	97 563	97 620	97 677	97 734	97 790	97 846	
19	97 358	97 414	97 471	97 528	97 585	97 641	97 697	
20	97 209	97 265	97 322	97 379	97 436	97 492	97 548	
21	97 061	97 117	97 174	97 231	97 287	97 343	97 406	
22	96 913	97 969	97 026	97 083	97 139	97 195	97 252	
23	96 766	96 822	96 879	96 936	96 992	97 048	97 105	
24	96 619	96 675	96 732	96 789	96 845	96 901	96 958	
25	96 473	96 529	96 586	96 643	96 699	96 755	96 812	145 1 14.5 2 29.0 3 43.5 4 58.0 5 72.5 6 87.0 7 101.5 8 116.0 9 130.5
26	96 327	96 383	96 440	96 497	96 553	96 609	96 666	
27	96 182	96 238	96 295	96 352	96 408	96 464	96 521	
28	96 037	96 093	96 150	96 207	96 263	96 319	96 367	
29	95 893	95 949	96 006	96 062	96 119	96 175	96 232	
30	95 749	95 806	95 863	95 919	95 976	96 032	96 088	
31	95 606	95 663	95 720	95 776	95 833	95 889	95 945	
32	95 463	95 520	95 577	95 633	95 690	95 746	95 802	
33	95 321	95 378	95 435	95 491	95 548	95 604	95 660	
34	95 179	95 236	95 293	95 349	95 406	95 462	95 518	

Table 16 (continued)

Temperature, °C	Corrected barometer reading P_0, mm Hg						
	772	773	774	775	776	777	778
	Logarithm of multiplier F						
5	99 890	99 946	00 002	00 058	00 114	00 170	00 226
6	99 734	99 790	99 846	99 902	99 958	00 014	00 070
7	99 579	99 635	99 691	99 747	99 803	99 859	99 914
8	99 424	99 480	99 536	99 592	99 648	99 704	99 759
9	99 269	99 325	99 381	99 437	99 493	99 549	99 605
10	99 115	99 171	99 227	99 283	99 339	99 395	99 451
11	98 962	99 018	99 073	99 129	99 185	99 241	99 297
12	98 809	98 865	98 920	98 976	99 032	99 089	99 144
13	98 656	98 712	98 768	98 824	98 880	98 937	98 992
14	98 504	98 560	98 616	98 672	98 728	98 784	98 840
15	98 353	98 409	98 465	98 521	98 577	98 633	98 689
16	98 202	98 258	98 314	98 370	98 426	98 482	98 538
17	98 052	98 108	98 164	98 220	98 276	98 332	98 388
18	97 902	97 958	98 014	98 070	98 126	98 182	98 238
19	97 753	97 800	97 865	97 921	97 977	98 033	98 089
20	97 604	97 660	97 716	97 772	97 828	97 904	97 940
21	97 456	97 512	97 568	97 624	97 680	97 736	97 792
22	97 308	97 364	97 420	97 476	97 532	97 588	97 644
23	97 161	97 217	97 273	97 329	97 385	97 441	97 497
24	97 014	97 070	97 126	97 182	97 238	97 294	97 350
25	96 868	96 924	96 980	97 036	97 092	97 148	97 204
26	96 722	96 778	96 834	96 890	96 946	97 002	97 058
27	96 577	96 633	96 689	96 745	96 801	96 858	96 913
28	96 432	96 488	96 544	96 600	96 656	96 712	96 768
29	96 288	96 344	96 400	96 456	96 512	96 568	96 624
30	96 145	96 201	96 257	96 313	96 369	96 425	96 481
31	96 002	96 058	96 114	96 170	96 226	96 282	96 338
32	95 859	95 915	95 971	96 027	96 083	96 139	96 195
33	95 717	95 773	95 829	95 885	95 941	95 997	96 053
34	95 575	95 631	95 687	95 743	95 799	95 855	95 911

Proportional parts	56	154	148	142
1	5.6	15.4	14.8	14.2
2	11.2	30.8	29.6	28.4
3	16.8	46.2	44.4	42.6
4	22.4	61.6	59.2	56.8
5	28.0	77.0	74.0	71.0
6	33.6	92.4	88.8	85.2
7	39.2	107.8	103.6	99.4
8	44.8	123.2	118.4	113.6
9	50.4	138.6	133.2	127.8

Table 16 (continued)

B. Vapour Pressure over Water and over Absorbing Solutions

Temperature, °C	Water	KOH solution, concentration of KOH in g per 100 g of water				Saturated NaCl solution	Temperature, °C
		10	20	30	40		
	Vapour pressure (P_B), mm Hg						
5	6.5	6.1	5.7	5.2	4.6	4.9	5
6	7.0	6.5	6.1	5.6	4.9	5.3	6
7	7.5	7.0	6.5	6.0	5.3	5.7	7
8	8.0	7.5	7.0	6.4	5.7	6.1	8
9	8.6	8.0	7.5	6.8	6.1	6.5	9
10	9.2	8.6	8.0	7.3	6.5	6.9	10
11	9.8	9.2	8.6	7.8	6.9	7.4	11
12	10.5	9.8	9.2	8.3	7.4	7.9	12
13	11.2	10.5	9.8	8.9	7.9	8.5	13
14	12.0	11.2	10.4	9.5	8.4	9.1	14
15	12.8	11.9	11.1	10.1	9.0	9.7	15
16	13.6	12.7	11.8	10.8	9.6	10.3	16
17	14.5	13.6	12.6	11.5	10.2	11.0	17
18	15.5	14.5	13.4	12.3	10.9	11.7	18
19	16.5	15.4	14.3	13.1	11.6	12.4	19
20	17.5	16.4	15.2	13.9	12.4	13.2	20
21	18.7	17.4	16.2	14.8	13.2	14.1	21
22	19.8	18.5	17.2	15.8	14.0	15.0	22
23	21.1	19.7	18.3	16.8	14.9	15.9	23
24	22.4	20.9	19.5	17.8	15.8	16.9	24
25	23.8	22.2	20.7	18.9	16.8	17.9	25
26	25.2	23.6	22.0	20.1	17.9	19.0	26
27	26.7	25.1	23.3	21.3	19.0	20.2	27
28	28.3	26.6	24.7	22.6	20.2	21.4	28
29	30.0	28.1	26.2	23.9	21.4	22.7	29
30	31.8	29.7	27.7	25.3	22.4	24.0	30
31	33.7	31.4	29.3	26.8	23.7	25.3	31
32	35.7	33.3	31.0	28.4	25.2	26.8	32
33	37.7	35.2	32.8	30.0	26.7	28.4	33
34	39.9	37.2	34.7	31.7	28.2	30.0	34

Table 16 (continued)

C. Densities of Gases and Vapours (ρ)

(Mass of one litre of gas or vapour in grams or one millilitre in milligrams under standard conditions)

Formula	Name	ρ, g/l (mg/ml)	log ρ
Ar	Argon	1.7837	25 132
AsF_5	Arsenic pentafluoride	7.71	88 705
AsH_3	Arseniuretted hydrogen, arsine	3.740	57 287
BF_3	Boron fluoride	3.21	50 650
CF_2Cl_2	Dichlorodifluoromethane, freon 12	5.510	74 115
CH_4	Methane	0.7168	85 540
C_2H_2	Acetylene, ethyne	1.173	06 930
C_2H_4	Ethylene, olefiant gas, ethene	1.2604	10 051
C_2H_6	Ethane	1.3566	13 245
C_3H_6	Propylene, propene	1.937	28 713
C_3H_8	Propane	2.0096	30 311
C_4H_{10}	Butane	2.5190	40 123
C_4H_{10}	Isobutane, methylpropane	2.6726	42 693
C_5H_{12}	Pentane	3.457	53 870
C_7H_{16}	Heptane	4.459	64 924
C_8H_{18}	Octane	5.030	70 157
CH_3Cl	Methyl chloride	2.3073	36 310
CH_3F	Methyl fluoride	1.5452	18 898
$CHCl_3$	Chloroform	5.283	72 288
CH_3NH_2	Methylamine	1.396	14 489
$(CH_3)_2NH$	Dimethylamine	2.089	31 994
$(CH_3)_3N$	Trimethylamine	2.619	41 814
$C_2H_5NH_2$	Ethylamine	2.0141	30 408
CH_3OH	Methanol, methyl alcohol	1.426	15 412
C_2H_5OH	Ethanol, ethyl alcohol	2.043	31 027
C_4H_9OH	Butanol, butyl alcohol	3.244	51 108
$(CN)_2$	Cyan, dicyan	2.335	36 829
$(CH_3)_2O$	Dimethyl ether	2.1098	32 424
CO	Carbon monoxide	1.2504	09 705
CO_2	Carbon dioxide	1.9769	29 598
$COCl_2$	Carbon oxychloride, phosgene	3.89	58 995
COS	Carbon oxysulphide	2.721	43 473
Cl_2	Chlorine	3.214	50 705
ClO_2	Chlorine dioxide	3.21	50 651
F_2	Fluorine	1.696	22 943
GeH_4	Germanium hydride	3.42	53 403
Ge_2H_6	Digermane	7.23	85 914
H_2	Hydrogen	0.08988	95 366
HBr	Hydrogen bromide	3.6445	56 164

Table 16 (continued)

Formula	Name	ρ, g/l (mg/ml)	log ρ
HCOH	Formaldehyde	1.34	12 716
HCl	Hydrogen chloride	1.6392	21 463
HF	Hydrogen fluoride	0.8940	95 134
HI	Hydrogen iodide	5.7891	76 261
H_2O	Steam	0.768	88 536
H_2S	Hydrogen sulphide	1.539	18 724
H_2Se	Hydrogen selenide	3.670	56 467
H_2Te	Hydrogen telluride	5.81	76 418
He	Helium	0.17847	25 157
Kr	Krypton	3.708	56 914
N_2	Nitrogen	1.25055	09 710
—	Air, mean value	1.2929	11 156
NH_3	Ammonia	0.7710	88 705
N_2O	Nitrous oxide	1.9778	29 618
NO	Nitrogen oxide	1.3402	12 717
NO_2	Nitrogen dioxide	2.055	31 281
NOCl	Nitrosyl chloride	2.9919	47 595
NOF	Nitrosyl fluoride	2.231	34 850
Ne	Neon	0.90035	95 441
O_2	Oxygen	1.42895	15 502
O_3	Ozone	2.144	33 122
OF_2	Oxygen fluoride	2.421	38 399
PH_3	Hydrogen phosphide, phosphine	1.5294	18 452
PF_5	Phosphorus pentafluoride	5.805	76 380
PF_3	Phosphorus trifluoride	3.907	59 184
POF_3	Phosphorus oxyfluoride	4.8	68 124
Rn	Radon	9.73	98 811
SF_6	Sulphur hexafluoride	6.98	84 386
SO_2	Sulphur dioxide	2.9269	46 641
SO_2F_2	Sulphuryl fluoride	3.99	60 097
SbH_3	Antimony hydride, stibine	5.59	74 741
SiF_4	Tetrafluorosilane	4.684	67 062
SiH_4	Silane, silicane	1.44	15 836
Si_2H_6	Disilicane	2.85	45 484
$SiH_2(CH_3)_2$	Dimethylsilane	2.73	43 616
SiH_3CH_3	Methylsilane	2.08	31 806
SiH_3Cl	Chlorosilane	3.03	48 144
SiH_2ClCH_3	Methylchlorosilane	3.64	56 110
$SiHCl_2CH_3$	Methyldichlorosilane	5.3	72 428
$SiHF_3$	Trifluorosilane	3.86	58 659
WF_6	Tungsten fluoride	12.9	11 059
Xe	Xenon	5.851	76 723

Table 16 (continued)

D. Gasometric (Volumetric) Determination of Gas-Forming Substances

Unknown substance		Measured gas	1 ml of measured gas under standard conditions corresponds to f' mg of the unknown substance	log f'
formula	name			
Al	Aluminium	H_2	0.8019	90 416
C	Carbon	CO_2	0.53954	73 202
CO_3^{2-}	Carbonate-ion	CO_2	2.6956	43 066
$CO(NH_2)_2$	Urea	N_2	2.6809	42 828
CaC_2	Calcium carbide	C_2H_2	2.8877	46 055
$CaCO_3$	Calcium carbonate	CO_2	4.4960	65 283
CaF_2	Calcium fluoride	SiF_4	7.0278	84 682
F	Fluorine	SiF_4	3.4200	53 403
Fe	Iron	H_2	2.4899	39 618
HNO_3	Nitric acid	NO	2.8144	44 939
H_2O_2	Hydrogen peroxide (treated with $KMnO_4$)	O_2	1.5191	18 158
H_2O_2	Hydrogen peroxide (catalytic decomposition)	O_2	3.0382	48 261
$KMnO_4$	Potassium permanganate (treated with H_2O_2)	O_2	2.8231	45 073
KNO_3	Potassium nitrate	NO	4.5159	65 474
Mg	Magnesium	H_2	1.0839	03 500
$MgCO_3$	Magnesium carbonate	CO_2	3.7877	57 838
N	Nitrogen	NO	0.62560	79 630
NH_4NO_3	Ammonium nitrate	NO	3.5751	55 329
NO_3^-	Nitrate-ion	NO	2.7694	44 239
N_2O_3	Nitrous anhydride	NO	1.6975	22 981
N_2O_5	Nitric anhydride	NO	2.4121	38 239
$NaNO_3$	Sodium nitrate	NO	3.7962	57 935
Ni	Nickel	H_2	2.6175	41 789
Na_2O_2	Sodium peroxide	O_2	6.965	84 291
Zn	Zinc	H_2	2.9145	46 456

Table 17

Conversion Formulas for Solution Concentrations

Notation: d = density of a solution, g/ml; M_w = molecular weight of a solute; E = equivalent weight of a solute

Concentration	A	B	C	N	M	L
In per cent (g per 100 g of a solution, wt. %), $A=$	A	$\frac{100B}{100+B}$	$\frac{C}{10d}$	$\frac{NE}{10d}$	$\frac{MM_w}{10d}$	$\frac{100LM_w}{1000+LM_w}$
In grams of a solute per 100 g of a solvent, $B=$	$\frac{100A}{100-A}$	B	$\frac{100C}{1000d-C}$	$\frac{100NE}{1000d-NE}$	$\frac{100MM_w}{1000d-MM_w}$	$\frac{LM_w}{10}$
In grams per litre of a solution (g/l), $C=$	$10Ad$	$\frac{1000Bd}{100+B}$	C	NE	MM_w	$\frac{1000LM_wd}{1000+LM_w}$
Normal, $N=$	$\frac{10Ad}{E}$	$\frac{1000Bd}{(100+B)E}$	$\frac{C}{E}$	N	$\frac{MM_w}{E}$	$\frac{1000LM_w}{(1000+LM_w)E}$
Molar, $M=$	$\frac{10Ad}{M_w}$	$\frac{1000Bd}{(100+B)M_w}$	$\frac{C}{M_w}$	$\frac{NE}{M_w}$	M	$\frac{1000Ld}{1000+M_wL}$
Molal (number of moles of a solute per 1000 g of a solvent), $L=$	$\frac{1000A}{(100-A)M_w}$	$\frac{10B}{M_w}$	$\frac{1000C}{(1000d-C)M_w}$	$\frac{1000NE}{(1000d-NE)M_w}$	$\frac{1000M}{1000d-MM_w}$	L

Table 18

Densities and Concentrations of Solutions

A. Densities and Concentrations of Nitric Acid Solutions*

Density at 20°C, g/cm³	HNO_3 concentration		Density at 20°C, g/cm³	HNO_3 concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.000	0.3333	0.05231	1.175	29.25	5.455
1.005	1.255	0.2001	1.180	30.00	5.618
1.010	2.164	0.3468	1.185	30.74	5.780
1.015	3.073	0.4950	1.190	31.47	5.943
1.020	3.982	0.6445	1.195	32.21	6.107
1.025	4.883	0.7943	1.200	32.94	6.273
1.030	5.784	0.9454	1.205	33.68	6.440
1.035	6.661	1.094	1.210	34.41	6.607
1.040	7.530	1.243	1.215	35.16	6.778
1.045	8.398	1.393	1.220	35.93	6.956
1.050	9.259	1.543	1.225	36.70	7.135
1.055	10.12	1.694	1.230	37.48	7.315
1.060	10.97	1.845	1.235	38.25	7.497
1.065	11.81	1.997	1.240	39.02	7.679
1.070	12.65	2.148	1.245	39.80	7.863
1.075	13.48	2.301	1.250	40.58	8.049
1.080	14.31	2.453	1.255	41.36	8.237
1.085	15.13	2.605	1.260	42.14	8.426
1.090	15.95	2.759	1.265	42.92	8.616
1.095	16.76	2.913	1.270	43.70	8.808
1.100	17.58	3.068	1.275	44.48	9.001
1.105	18.39	3.224	1.280	45.27	9.195
1.110	19.19	3.381	1.285	46.06	9.394
1.115	20.00	3.539	1.290	46.85	9.590
1.120	20.79	3.696	1.295	47.63	9.789
1.125	21.59	3.854	1.300	48.42	9.990
1.130	22.38	4.012	1.305	49.21	10.19
1.135	23.16	4.171	1.310	50.00	10.39
1.140	23.94	4.330	1.315	50.85	10.61
1.145	24.71	4.489	1.320	51.71	10.83
1.150	25.48	4.649	1.325	52.56	11.05
1.155	26.24	4.810	1.330	53.41	11.27
1.160	27.00	4.970	1.335	54.27	11.49
1.165	27.76	5.132	1.340	55.13	11.72
1.170	28.51	5.293	1.345	56.04	11.96

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* For the use of the table, see p. 470.

Table 18 (continued)

Density at 20°C, g/cm^3	HNO_3 concentration		Density at 20°C, g/cm^3	HNO_3 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.350	56.95	12.20	1.460	82.39	19.09
1.355	57.87	12.44	1.465	83.91	19.51
1.360	58.78	12.68	1.470	85.50	19.95
1.365	59.69	12.93	1.475	87.29	20.43
1.370	60.67	13.19	1.480	89.07	20.92
1.375	61.69	13.46	1.485	91.13	21.48
1.380	62.70	13.73	1.490	93.49	22.11
1.385	63.72	14.01	1.495	95.46	22.65
1.390	64.74	14.29	1.500	96.73	23.02
1.395	65.84	14.57	1.501	96.98	23.10
1.400	66.97	14.88	1.502	97.23	23.18
1.405	68.10	15.18	1.503	97.49	23.25
1.410	69.23	15.49	1.504	97.74	23.33
1.415	70.39	15.81	1.505	97.99	23.40
1.420	71.63	16.14	1.506	98.25	23.48
1.425	72.86	16.47	1.507	98.50	23.56
1.430	74.09	16.81	1.508	98.76	23.63
1.435	75.35	17.16	1.509	99.01	23.71
1.440	76.71	17.53	1.510	99.26	23.79
1.445	78.07	17.90	1.511	99.52	23.86
1.450	79.43	18.28	1.512	99.77	23.94
1.455	80.88	18.68	1.513	100.00	24.01

B. Densities and Concentrations of Sulphuric Acid Solutions*

Density at 20°C, g/cm^3	H_2SO_4 concentration		Density at 20°C, g/cm^3	H_2SO_4 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.000	0.2609	0.02660	1.045	6.956	0.7411
1.005	0.9855	0.1010	1.050	7.704	0.8250
1.010	1.731	0.1783	1.055	8.415	0.9054
1.015	2.485	0.2595	1.060	9.129	0.9865
1.020	3.242	0.3372	1.065	9.843	1.066
1.025	4.000	0.4180	1.070	10.56	1.152
1.030	4.746	0.4983	1.075	11.26	1.235
1.035	5.493	0.5796	1.080	11.96	1.317
1.040	6.237	0.6613	1.085	12.66	1.401

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* For the use of the table, see p. 470.

Table 18 (continued)

Density at 20°C, g/cm³	H_2SO_4 concentration		Density at 20°C, g/cm³	H_2SO_4 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.090	13.36	1.484	1.300	39.68	5.259
1.095	14.04	1.567	1.305	40.25	5.356
1.100	14.73	1.652	1.310	40.82	5.452
1.105	15.41	1.735	1.315	41.39	5.549
1.110	16.08	1.820	1.320	41.95	5.646
1.115	16.76	1.905	1.325	42.51	5.743
1.120	17.43	1.990	1.330	43.07	5.840
1.125	18.09	2.075	1.335	43.62	5.938
1.130	18.76	2.161	1.340	44.17	6.035
1.135	19.42	2.247	1.345	44.72	6.132
1.140	20.08	2.334	1.350	45.26	6.229
1.145	20.73	2.420	1.355	45.80	6.327
1.150	21.38	2.507	1.360	46.33	6.424
1.155	22.03	2.594	1.365	46.86	6.522
1.160	22.67	2.681	1.370	47.39	6.620
1.165	23.31	2.768	1.375	47.92	6.718
1.170	23.95	2.857	1.380	48.45	6.817
1.175	24.58	2.945	1.385	48.97	6.915
1.180	25.21	3.033	1.390	49.48	7.012
1.185	25.84	3.122	1.395	49.99	7.110
1.190	26.47	3.211	1.400	50.50	7.208
1.195	27.10	3.302	1.405	51.01	7.307
1.200	27.72	3.391	1.410	51.52	7.406
1.205	28.33	3.481	1.415	52.02	7.505
1.210	28.95	3.572	1.420	52.51	7.603
1.215	29.57	3.663	1.425	53.01	7.702
1.220	30.18	3.754	1.430	53.50	7.801
1.225	30.79	3.846	1.435	54.00	7.901
1.230	31.40	3.938	1.440	54.49	8.000
1.235	32.01	4.031	1.445	54.97	8.099
1.240	32.61	4.123	1.450	55.45	8.198
1.245	33.22	4.216	1.455	55.93	8.297
1.250	33.82	4.310	1.460	56.41	8.397
1.255	34.42	4.404	1.465	56.89	8.497
1.260	35.01	4.498	1.470	57.36	8.598
1.265	35.60	4.592	1.475	57.84	8.699
1.270	36.19	4.686	1.480	58.31	8.799
1.275	36.78	4.781	1.485	58.78	8.899
1.280	37.36	4.876	1.490	59.24	9.000
1.285	37.95	4.972	1.495	59.70	9.100
1.290	38.53	5.068	1.500	60.17	9.202
1.295	39.10	5.163	1.505	60.62	9.303

Table 18 (continued)

Density at 20°C, g/cm³	H_2SO_4 concentration		Density at 20°C, g/cm³	H_2SO_4 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.510	61.08	9.404	1.705	78.06	13.57
1.515	61.54	9.506	1.710	78.49	13.69
1.520	62.00	9.608	1.715	78.93	13.80
1.525	62.45	9.711	1.720	79.37	13.92
1.530	62.91	9.813	1.725	79.81	14.04
1.535	63.36	9.916	1.730	80.25	14.16
1.540	63.81	10.02	1.735	80.70	14.28
1.545	64.26	10.12	1.740	81.16	14.40
1.550	64.71	10.23	1.745	81.62	14.52
1.555	65.15	10.33	1.750	82.09	14.65
1.560	65.59	10.43	1.755	82.57	14.78
1.565	66.03	10.54	1.760	83.06	14.90
1.570	66.47	10.64	1.765	83.57	15.04
1.575	66.91	10.74	1.770	84.08	15.17
1.580	67.35	10.85	1.775	84.61	15.31
1.585	67.79	10.96	1.780	85.16	15.46
1.590	68.23	11.06	1.785	85.74	15.61
1.595	68.66	11.16	1.790	86.35	15.76
1.600	69.09	11.27	1.795	86.99	15.92
1.605	69.53	11.38	1.800	87.69	16.09
1.610	69.96	11.48	1.805	88.43	16.27
1.615	70.39	11.59	1.810	89.23	16.47
1.620	70.82	11.70	1.815	90.12	16.68
1.625	71.25	11.80	1.820	91.11	16.91
1.630	71.67	11.91	1.821	91.33	16.96
1.635	72.09	12.02	1.822	91.56	17.01
1.640	72.52	12.13	1.823	91.78	17.06
1.645	72.95	12.24	1.824	92.00	17.11
1.650	73.37	12.34	1.825	92.25	17.17
1.655	73.80	12.45	1.826	92.51	17.22
1.660	74.22	12.56	1.827	92.77	17.28
1.665	74.64	12.67	1.828	93.03	17.34
1.670	75.07	12.78	1.829	93.33	17.40
1.675	75.49	12.89	1.830	93.64	17.47
1.680	75.92	13.00	1.831	93.94	17.54
1.685	76.34	13.12	1.832	94.32	17.62
1.690	76.77	13.23	1.833	94.72	17.70
1.695	77.20	13.34	1.834	95.12	17.79
1.700	77.63	13.46	1.835	95.72	17.91

Table 18 (continued)

C. Densities and Concentrations of Hydrochloric Acid Solutions*

Density at 20°C, g/cm³	HCl concentration: g per 100 g of solution (wt.%)	HCl concentration: mole/l	Density at 20°C, g/cm³	HCl concentration: g per 100 g of solution (wt.%)	HCl concentration: mole/l
1.000	0.3600	0.09872	1.105	21.36	6.472
1.005	1.360	0.3748	1.110	22.33	6.796
1.010	2.364	0.6547	1.115	23.29	7.122
1.015	3.374	0.9391	1.120	24.25	7.449
1.020	4.388	1.227	1.125	25.22	7.782
1.025	5.408	1.520	1.130	26.20	8.118
1.030	6.433	1.817	1.135	27.18	8.459
1.035	7.464	2.118	1.140	28.18	8.809
1.040	8.490	2.421	1.145	29.17	9.159
1.045	9.510	2.725	1.150	30.14	9.505
1.050	10.52	3.029	1.155	31.14	9.863
1.055	11.52	3.333	1.160	32.14	10.22_5
1.060	12.51	3.638	1.165	33.16	10.59_5
1.065	13.50	3.944	1.170	34.18	10.97
1.070	14.49_5	4.253	1.175	35.20	11.34
1.075	15.48_5	4.565	1.180	36.23	11.73
1.080	16.47	4.878	1.185	37.27	12.11
1.085	17.45	5.192	1.190	38.32	12.50
1.090	18.43	5.509_5	1.195	39.37	12.90
1.095	19.41	5.829	1.198	40.00	13.14
1.100	20.39	6.150			

Concentrations of Hydrochloric Acid Having Constant Boiling Point

Atmospheric pressure during distillation, mm Hg	780	770	760	750	740	730
Hydrochloric acid concentration (reduced to a vacuum), g of HCl per 100 g of solution	20.173	20.197	20.221	20.245	20.269	20.293
Mass of distillate containing exactly 1 mole of HCl (weighing performed in air), g	180.621	180.407	180.193	179.979	179.766	179.551

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* For the use of the table, see p. 470.

Table 18 (continued)

D. Densities and Concentrations of Phosphoric Acid Solutions*

Density at 20°C, g/cm³	H_3PO_4 concentration		Density at 20°C, g/cm³	H_3PO_4 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.000	0.296	0.030	1.195	32.05	3.908
1.005	1.222	0.1253	1.200	32.75	4.010
1.010	2.148	0.2214	1.205	33.44	4.112
1.015	3.074	0.3184	1.210	34.13	4.215
1.020	4.000	0.4164	1.215	34.82	4.317
1.025	4.926	0.5152	1.220	35.50	4.420
1.030	5.836	0.6134	1.225	36.17	4.522
1.035	6.745	0.7124	1.230	36.84	4.624
1.040	7.643	0.8110	1.235	37.51	4.727
1.045	8.536	0.911	1.240	38.17	4.829
1.050	9.429	1.010	1.245	38.83	4.932
1.055	10.32	1.111	1.250	39.49	5.036
1.060	11.19	1.210	1.255	40.14	5.140
1.065	12.06	1.311	1.260	40.79	5.245
1.070	12.92	1.411	1.265	41.44	5.350
1.075	13.76	1.510	1.270	42.09	5.454
1.080	14.60	1.609	1.275	42.73	5.559
1.085	15.43	1.708	1.280	43.37	5.655
1.090	16.26	1.807	1.285	44.00	5.771
1.095	17.07	1.906	1.290	44.63	5.875
1.100	17.87	2.005	1.295	45.26	5.981
1.105	18.68	2.105	1.300	45.88	6.087
1.110	19.46	2.204	1.305	46.49	6.191
1.115	20.25	2.304	1.310	47.10	6.296
1.120	21.03	2.403	1.315	47.70	6.400
1.125	21.80	2.502	1.320	48.30	6.506
1.130	22.56	2.602	1.325	48.89	6.610
1.135	23.32	2.702	1.330	49.48	6.716
1.140	24.07	2.800	1.335	50.07	6.822
1.145	24.82	2.900	1.340	50.66	6.928
1.150	25.57	3.000	1.345	51.25	7.034
1.155	26.31	3.101	1.350	51.84	7.141
1.160	27.05	3.203	1.355	52.42	7.247
1.165	27.78	3.304	1.360	53.00	7.355
1.170	28.51	3.404	1.365	53.57	7.463
1.175	29.23	3.505	1.370	54.14	7.570
1.180	29.94	3.606	1.375	54.71	7.678
1.185	30.65	3.707	1.380	55.28	7.784
1.190	31.35	3.806	1.385	55.85	7.894

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* For the use of the table, see p. 470.

Table 18 (*continued*)

Density at 20°C, g/cm^3	H_3PO_4 concentration		Density at 20°C, g/cm^3	H_3PO_4 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.390	56.42	8.004	1.600	77.60	12.67
1.395	56.98	8.112	1.605	78.05	12.78
1.400	57.54	8.221	1.610	78.50	12.90
1.405	58.09	8.328	1.615	78.95	13.01
1.410	58.64	8.437	1.620	79.40	13.12
1.415	59.19	8.547	1.625	79.85	13.24
1.420	59.74	8.658	1.630	80.30	13.36
1.425	60.29	8.766	1.635	80.75	13.48
1.430	60.84	8.878	1.640	81.20	13.59
1.435	61.38	8.989	1.645	81.64	13.71
1.440	61.92	9.099	1.650	82.08	13.82
1.445	62.45	9.208	1.655	82.52	13.94
1.450	62.98	9.322	1.660	82.96	14.06
1.455	63.51	9.432	1.665	83.39	14.17
1.460	64.03	9.541	1.670	83.82	14.29
1.465	64.55	9.651	1.675	84.25	14.40
1.470	65.07	9.761	1.680	84.68	14.52
1.475	65.58	9.870	1.685	85.11	14.63
1.480	66.09	9.982	1.690	85.54	14.75
1.485	66.60	10.09	1.695	85.96	14.87
1.490	67.10	10.21	1.700	86.38	14.98
1.495	67.60	10.31	1.705	86.80	15.10
1.500	68.10	10.42	1.710	87.22	15.22
1.505	68.60	10.53	1.715	87.64	15.33
1.510	69.09	10.64	1.720	88.06	15.45
1.515	69.58	10.76	1.725	88.48	15.57
1.520	70.07	10.86	1.730	88.90	15.70
1.525	70.56	10.98	1.735	89.31	15.81
1.530	71.04	11.09	1.740	89.72	15.93
1.535	71.52	11.20	1.745	90.13	16.04
1.540	72.00	11.32	1.750	90.54	16.16
1.545	72.48	11.42	1.755	90.95	16.29
1.550	72.95	11.53	1.760	91.36	16.41
1.555	73.42	11.65	1.765	91.77	16.53
1.560	73.89	11.76	1.770	92.17	16.65
1.565	74.36	11.88	1.775	92.57	16.77
1.570	74.83	11.99	1.780	92.97	16.89
1.575	75.30	12.11	1.785	93.37	17.00
1.580	75.76	12.22	1.790	93.77	17.13
1.585	76.22	12.33	1.795	94.17	17.25
1.590	76.68	12.45	1.800	94.57	17.37
1.595	77.14	12.56	1.805	94.97	17.50

Table 18 (continued)

Density at 20°C, g/cm³	H_3PO_4 concentration		Density at 20°C, g/cm³	H_3PO_4 concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.810	95.37	17.62	1.845	98.10	18.47
1.815	95.76	17.74	1.850	98.48	18.60
1.820	96.15	17.85	1.855	98.86	18.72
1.825	96.54	17.98	1.860	99.24	18.84
1.830	96.93	18.10	1.865	99.62	18.96
1.835	97.32	18.23	1.870	100.00	19.08
1.840	97.71	18.34			

E. Densities and Concentrations of Perchloric Acid Solutions*

Density at 20°C, g/cm³	$HClO_4$ concentration		Density at 20°C, g/cm³	$HClO_4$ concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.005	1.00	0.1004	1.120	18.88	2.105
1.010	1.90	0.1910	1.125	19.57	2.191
1.015	2.77	0.2799	1.130	20.26	2.279
1.020	3.61	0.3665	1.135	20.95	2.367
1.025	4.43	0.4520	1.140	21.64	2.456
1.030	5.25	0.5383	1.145	22.32	2.544
1.035	6.07	0.6253	1.150	22.99	2.632
1.040	6.88	0.7122	1.155	23.65	2.719
1.045	7.68	0.7989	1.160	24.30	2.806
1.050	8.48	0.8863	1.165	24.94	2.892
1.055	9.28	0.9745	1.170	25.57	2.978
1.060	10.06	1.061	1.175	26.20	3.064
1.065	10.83	1.148	1.180	26.82	3.150
1.070	11.58	1.233	1.185	27.44	3.237
1.075	12.33	1.319	1.190	28.05	3.323
1.080	13.08	1.406	1.195	28.66	3.409
1.085	13.83	1.494	1.200	29.26	3.495
1.090	14.56	1.580	1.205	29.86	3.582
1.095	15.28	1.665	1.210	30.45	3.667
1.100	16.00	1.752	1.215	31.04	3.754
1.105	16.72	1.839	1.220	31.61	3.839
1.110	17.45	1.928	1.225	32.18	3.924
1.115	18.16	2.015	1.230	32.74	4.008

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* For the use of the table, see p. 470.

Table 18 (continued)

Density at 20°C, g/cm³	$HClO_4$ concentration		Density at 20°C, g/cm³	$HClO_4$ concentration	
	g per 100 g of solution (wt.%)	mole/l		g per 100 g of solution (wt.%)	mole/l
1.235	33.29	4.092	1.445	52.89	7.607
1.240	33.85	4.178	1.450	53.27	7.689
1.245	34.40	4.263	1.455	53.65	7.770
1.250	34.95	4.349	1.460	54.03	7.852
1.255	35.49	4.433	1.465	54.41	7.934
1.260	36.03	4.519	1.470	54.79	8.017
1.265	36.56	4.604	1.475	55.17	8.100
1.270	37.08	4.687	1.480	55.55	8.183
1.275	37.60	4.772	1.485	55.93	8.267
1.280	38.10	4.854	1.490	56.31	8.352
1.285	38.60	4.937	1.495	56.69	8.436
1.290	39.10	5.021	1.500	57.06	8.519
1.295	39.60	5.105	1.505	57.44	8.605
1.300	40.10	5.189	1.510	57.81	8.689
1.305	40.59	5.273	1.515	58.17	8.772
1.310	41.08	5.357	1.520	58.54	8.857
1.315	41.56	5.440	1.525	58.91	8.942
1.320	42.02	5.521	1.530	59.28	9.028
1.325	42.49	5.604	1.535	59.66	9.116
1.330	42.97	5.689	1.540	60.04	9.203
1.335	43.43	5.771	1.545	60.41	9.290
1.340	43.89	5.854	1.550	60.78	9.377
1.345	44.35	5.937	1.555	61.15	9.465
1.350	44.81	6.021	1.560	61.52	9.553
1.355	45.26	6.104	1.565	61.89	9.641
1.360	45.71	6.188	1.570	62.26	9.730
1.365	46.16	6.272	1.575	62.63	9.819
1.370	46.61	6.356	1.580	63.00	9.908
1.375	47.05	6.439	1.585	63.37	9.998
1.380	47.49	6.523	1.590	63.74	10.09
1.385	47.93	6.608	1.595	64.12	10.18
1.390	48.37	6.692	1.600	64.50	10.27
1.395	48.80	6.776	1.605	64.88	10.37
1.400	49.23	6.860	1.610	65.26	10.46
1.405	49.68	6.948	1.615	65.63	10.55
1.410	50.10	7.032	1.620	66.01	10.64
1.415	50.51	7.114	1.625	66.39	10.74
1.420	50.90	7.196	1.630	66.76	10.83
1.425	51.31	7.278	1.635	67.13	10.93
1.430	51.71	7.360	1.640	67.51	11.02
1.435	52.11	7.443	1.645	67.89	11.12
1.440	52.51	7.527	1.650	68.26	11.21

Table 18 (continued)

Density at 20°C, g/cm³	$HClO_4$ concentration		Density at 20°C, g/cm³	$HClO_4$ concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.655	68.64	11.31	1.670	69.77	11.60
1.660	69.02	11.40	1.675	70.15	11.70
1.665	69.40	11.50			

F. Densities and Concentrations of Acetic Acid Solutions*

Density at 20°C, g/cm³	CH_3COOH concentration		Density at 20°C, g/cm³	CH_3COOH concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.000	1.20	0.200	1.050	40.2	7.03
1.005	4.64	0.777	1.055	46.9	8.24
1.010	8.14	1.37	1.060	53.4	9.43
1.015	11.7	1.98	1.065	61.4	10.9
1.020	15.4	2.61	1.070	77-79**	13.7-14.1
1.025	19.2	3.27	1.065	91.2	16.2
1.030	23.1	3.96	1.060	95.4	16.8
1.035	27.2	4.68	1.055	98.0	17.2
1.040	31.6	5.46	1.050	99.9	17.5
1.045	36.2	6.30			

** Acetic acid, in the given limits of concentration, has a density of 1.0700 g/cm³ with deviations of less than 0.0001. Since density decreases with a further increase in concentration, then in order to determine the concentration from two possible ones that meets the density found (for example, the density of the solution is 1.060 g/cm³; will its concentration be 53.4% or 95.4%?), a little water is added to the acetic acid test. If the density decreases, a lower concentration is taken (in the given case, 53.4%), and if it increases, a higher concentration is taken (in the given case, 95.4%).

G. Densities and Concentrations of Potassium Hydroxide Solutions*

Density at 20°C, g/cm³	KOH concentration		Density at 20°C, g/cm³	KOH concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.000	0.197	0.0351	1.015	1.84	0.333
1.005	0.743	0.133	1.020	2.38	0.433_5
1.010	1.29_5	0.233	1.025	2.93	0.536

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* For the use of the table, see p. 470.

Table 18 (continued)

Density at 20°C, g/cm³	KOH concentration		Density at 20°C, g/cm³	KOH concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.030	3.48	0.639_5	1.240	25.36	5.60
1.035	4.03	0.744	1.245	25.85	5.74
1.040	4.58	0.848	1.250	26.34	5.87
1.045	5.12	0.954	1.255	26.83	6.00
1.050	5.66	1.06	1.260	27.32	6.13_5
1.055	6.20	1.17	1.265	27.80	6.27
1.060	6.74	1.27	1.270	28.29	6.40
1.065	7.28	1.38	1.275	28.77	6.54
1.070	7.82	1.49	1.280	29.25	6.67
1.075	8.36	1.60	1.285	29.73	6.81
1.080	8.89	1.71	1.290	30.21	6.95
1.085	9.43	1.82	1.295	30.68	7.08
1.090	9.96	1.94	1.300	31.15	7.22
1.095	10.49	2.05	1.305	31.62	7.36
1.100	11.03	2.16	1.310	32.09	7.49
1.105	11.56	2.28	1.315	32.56	7.63
1.110	12.08	2.39	1.320	33.03	7.77
1.115	12.61	2.51	1.325	33.50	7.91
1.120	13.14	2.62	1.330	33.97	8.05
1.125	13.66	2.74	1.335	34.43	8.19
1.130	14.19	2.86	1.340	34.90	8.33_5
1.135	14.70_5	2.97_5	1.345	35.36	8.48
1.140	15.22	3.09	1.350	35.82	8.62
1.145	15.74	3.21	1.355	36.28	8.76
1.150	16.26	3.33	1.360	36.73_5	8.90_5
1.155	16.78	3.45	1.365	37.19	9.05
1.160	17.29	3.58	1.370	37.65	9.19
1.165	17.81	3.70	1.375	38.10_5	9.34
1.170	18.32	3.82	1.380	38.56	9.48
1.175	18.84	3.94_5	1.385	39.01	9.63
1.180	19.35	4.07	1.390	39.46	9.78
1.185	19.86	4.19_5	1.395	39.92	9.93
1.190	20.37	4.32	1.400	40.37	10.07
1.195	20.88	4.45	1.405	40.82	10.22
1.200	21.38	4.57	1.410	41.26	10.37
1.205	21.88	4.70	1.415	41.71	10.52
1.210	22.38	4.83	1.420	42.15_5	10.67
1.215	22.88	4.95_5	1.425	42.60	10.82
1.220	23.38	5.08	1.430	43.04	10.97
1.225	23.87	5.21	1.435	43.48	11.12
1.230	24.37	5.34	1.440	43.92	11.28
1.235	24.86	5.47	1.445	44.36	11.42

Table 18 (continued)

Density at 20°C, g/cm³	KOH concentration		Density at 20°C, g/cm³	KOH concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.450	44.79	11.58	1.495	48.67_5	12.97
1.455	45.23	11.73	1.500	49.10	13.13
1.460	45.66	11.88	1.505	49.53	13.29
1.465	46.09_5	12.04	1.510	49.95	13.45
1.470	46.53	12.19	1.515	50.38	13.60
1.475	46.96	12.35	1.520	50.80	13.76
1.480	47.39	12.50	1.525	51.22	13.92
1.485	47.82	12.66	1.530	51.64	14.08
1.490	48.25	12.82	1.535	52.05	14.24

H. Densities and Concentrations of Caustic Soda Solutions*

Density at 20°C, g/cm³	NaOH concentration		Density at 20°C, g/cm³	NaOH concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.000	0.159	0.0398	1.105	9.64_5	2.664
1.005	0.602	0.151	1.110	10.10	2.802
1.010	1.04_5	0.264	1.115	10.55_5	2.942
1.015	1.49	0.378	1.120	11.01	3.082
1.020	1.94	0.494	1.125	11.46	3.224
1.025	2.39	0.611	1.130	11.92	3.367
1.030	2.84	0.731	1.135	12.37	3.510
1.035	3.29	0.851	1.140	12.83	3.655
1.040	3.74_5	0.971	1.145	13.28	3.801
1.045	4.20	1.097	1.150	13.73	3.947
1.050	4.65_5	1.222	1.155	14.18	4.095
1.055	5.11	1.347	1.160	14.64	4.244
1.060	5.56	1.474	1.165	15.09	4.395
1.065	6.02	1.602	1.170	15.54	4.545
1.070	6.47	1.731	1.175	15.99	4.697
1.075	6.93	1.862	1.180	16.44	4.850
1.080	7.38	1.992	1.185	16.89	5.004
1.085	7.83	2.123	1.190	17.34_5	5.160
1.090	8.28	2.257	1.195	17.80	5.317
1.095	8.74	2.391	1.200	18.25_5	5.476
1.100	9.19	2.527	1.205	18.71	5.636

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* For the use of the table, see p. 470.

Table 18 (continued)

Density at 20°C, g/cm^3	NaOH concentration		Density at 20°C, g/cm^3	NaOH concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.210	19.16	5.796	1.375	34.52	11.86
1.215	19.62	5.958	1.380	35.01	12.08
1.220	20.07	6.122	1.385	35.50_5	12.29
1.225	20.53	6.286	1.390	36.00	12.51
1.230	20.98	6.451	1.395	36.49_5	12.73
1.235	21.44	6.619	1.400	36.99	12.95
1.240	21.90	6.788	1.405	37.49	13.17
1.245	22.36	6.958	1.410	37.99	13.39
1.250	22.82	7.129	1.415	38.49	13.61
1.255	23.27_5	7.302	1.420	38.99	13.84
1.260	23.73	7.475	1.425	39.49_5	14.07
1.265	24.19	7.650	1.430	40.00	14.30
1.270	24.64_5	7.824	1.435	40.51_5	14.53
1.275	25.10	8.000	1.440	41.03	14.77
1.280	25.56	8.178	1.445	41.55	15.01
1.285	26.02	8.357	1.450	42.07	15.25
1.290	26.48	8.539	1.455	42.59	15.49
1.295	26.94	8.722	1.460	43.12	15.74
1.300	27.41	8.906	1.465	43.64	15.98
1.305	27.87	9.092	1.470	44.17	16.23
1.310	28.33	9.278	1.475	44.69_5	16.48
1.315	28.80	9.466	1.480	45.22	16.73
1.320	29.26	9.656	1.485	45.75	16.98
1.325	29.73	9.847	1.490	46.27	17.23
1.330	30.20	10.04	1.495	46.80	17.49
1.335	30.67	10.23	1.500	47.33	17.75
1.340	31.14	10.43	1.505	47.85	18.00
1.345	31.62	10.63	1.510	48.38	18.26
1.350	32.10	10.83	1.515	48.90_5	18.52
1.355	32.58	11.03	.520	49.44	18.78
1.360	33.06	11.24	1.525	49.97	19.05
1.365	33.54	11.45	1.530	50.50	19.31
1.370	34.03	11.65			

I. Densities and Concentrations of Ammonia Solutions*

Density at 20°C, g/cm^3	NH_3 concentration		Density at 20°C, g/cm^3	NH_3 concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
0.998	0.0465	0.0273	0.994	0.977	0.570
0.996	0.512	0.299	0.992	1.43	0.834

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*For the use of the table, see p. 470.

Table 18 (continued)

Density at 20°C, g/cm³	NH_3 concentration		Density at 20°C, g/cm³	NH_3 concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
0.990	1.89	1.10	0.934	16.65	9.13
0.988	2.35	1.36_5	0.932	17.24	9.44
0.986	2.82	1.63_5	0.930	17.85	9.75
0.984	3.30	1.91	0.928	18.45	10.06
0.982	3.78	2.18	0.926	19.06	10.37
0.980	4.27	2.46	0.924	19.67	10.67
0.978	4.76	2.73	0.922	20.27	10.97
0.976	5.25	3.01	0.920	20.88	11.28
0.974	5.75	3.29	0.918	21.50	11.59
0.972	6.25	3.57	0.916	22.12_5	11.90
0.970	6.75	3.84	0.914	22.75	12.21
0.968	7.26	4.12	0.912	23.39	12.52
0.966	7.77	4.41	0.910	24.03	12.84
0.964	8.29	4.69	0.908	24.68	13.16
0.962	8.82	4.98	0.906	25.33	13.48
0.960	9.34	5.27	0.904	26.00	13.80
0.958	9.87	5.55	0.902	26.67	14.12
0.956	10.40_5	5.84	0.900	27.33	14.44
0.954	10.95	6.13	0.898	28.00	14.76
0.952	11.49	6.42	0.896	28.67	15.08
0.950	12.03	6.71	0.894	29.33	15.40
0.948	12.58	7.00	0.892	30.00	15.71
0.946	13.14	7.29	0.890	30.68_5	16.04
0.944	13.71	7.60	0.888	31.37	16.36
0.942	14.29	7.91	0.886	32.09	16.69
0.940	14.88	8.21	0.884	32.84	17.05
0.938	15.47	8.52	0.882	33.59_5	17.40
0.936	16.06	8.83	0.880	34.35	17.75

J. Densities and Concentrations of Sodium Carbonate Solutions

Density at 20°C, g/cm³	Na_2CO_3 (anhydrous) concentration		Density at 20°C, g/cm³	Na_2CO_3 (anhydrous) concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.000	0.19	0.018	1.025	2.57	0.248
1.005	0.67	0.063_5	1.030	3.05	0.296
1.010	1.14	0.109	1.035	3.54	0.346
1.015	1.62	0.155	1.040	4.03	0.395
1.020	2.10	0.202	1.045	4.50	0.444

Table 18 (continued)

Density at 20°C, g/cm^3	Na_2CO_3 (anhydrous) concentration		Density at 20°C, g/cm^3	Na_2CO_3 (anhydrous) concentration	
	g per 100 g of solution (wt. %)	mole/l		g per 100 g of solution (wt. %)	mole/l
1.050	4.98	0.493	1.125	12.05	1.279
1.055	5.47	0.544	1.130	12.52	1.335
1.060	5.95	0.595	1.135	13.00	1.392
1.065	6.43	0.646	1.140	13.45	1.446
1.070	6.90	0.696	1.145	13.90	1.501
1.075	7.38	0.748	1.150	14.35	1.557
1.080	7.85	0.800	1.155	14.75	1.607
1.085	8.33	0.853	1.160	15.20	1.663
1.090	8.80	0.905	1.165	15.60	1.714
1.095	9.27	0.958	1.170	16.03	1.769
1.100	9.75	1.012	1.175	16.45	1.823
1.105	10.22	1.065	1.180	16.87	1.878
1.110	10.68	1.118	1.185	17.30	1.934
1.115	11.14	1.172	1.190	17.70	1.987
1.120	11.60	1.226			

K. Densities and Concentrations of Selected Commercial Reagents

Reagent	Density at 20°C, g/cm^3	Concentration	
		wt. %	mole/l
Acetic acid, analytical grade and pure	$\leqslant 1.0549$	$\geqslant 98$	$\geqslant 17.21$
Acetic acid, glacial, chemically pure	$\leqslant 1.0503$	$\geqslant 99.8$	$\geqslant 17.45$
Ammonia solution, concentrated	0.901-0.907	25.0-27.0	13.32-14.28
Hydrobromic acid	1.486	46.85	8.6
Hydrochloric acid	1.174-1.185	35.0-38.0	11.27-12.38
Hydrofluoric acid, analytical grade	$\geqslant 1.128$	$\geqslant 40$	$\geqslant 22.55$
Hydrofluoric acid, pure	$\geqslant 1.116$	$\geqslant 35$	$\geqslant 19.52$
Hydroiodic acid	1.50-1.55	45.3-45.8	5.31-5.55
Nitric acid, "strong" . .	1.372-1.405	60.7-68.0	13.28-15.16
Nitric acid, "weak" . . .	1.337-1.367	54.0-60.0	11.41-13.02

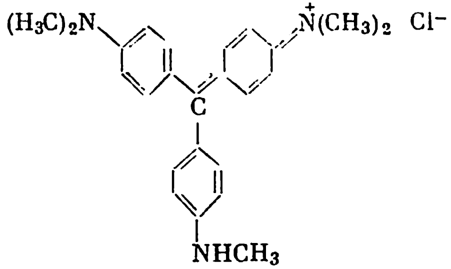
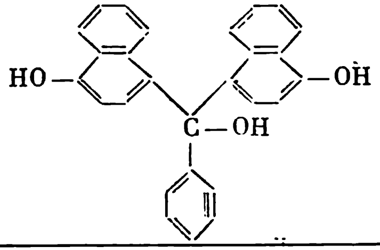
Table 18 (continued)

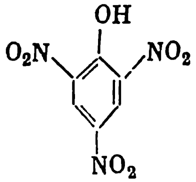
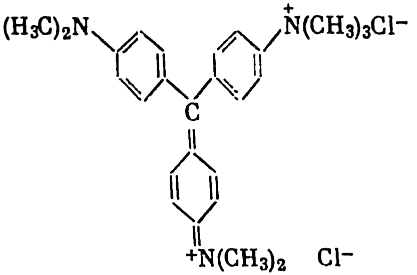
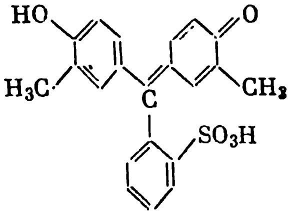
Reagent	Density at 20°C, g/cm³	Concentration	
		wt. %	mole/l
Perchloric acid	1.206-1.220	30.0-31.61	3.60-3.84
Phosphoric acid, analytical grade	$\geqslant$1.719	$\geqslant$88	$\geqslant$15.43
Phosphoric acid, pure	$\geqslant$1.713	$\geqslant$87.5	$\geqslant$15.29
Sulphuric acid	1.83-1.835	93.56-95.60	17.46-17.88

Table 19

Chief Acid-Base Indicators*

(in the order of the growth in the pH range)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
1	Methyl violet; first change (see Nos. 7 and 15)	 (predominantly)	0.1 and 0.05	Water	0.13-0.5 yellow — green
2	α-Naphtholbenzoin; first change (see No. 57)		0.05	70% alcohol	0.0-1.0 green — yellow

3	Picric acid (2,4,6-trinitrophenol)		0.1	Water	0.0-1.3 colourless—yellow
4	Methyl green		0.05	Water	0.1-2.0 yellow—green-blue
5	Cresol red (*o*-cresolsulphophthalein); first change		0.04	50% alcohol	0.2-1.8 red—yellow

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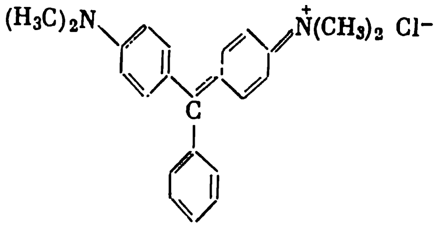
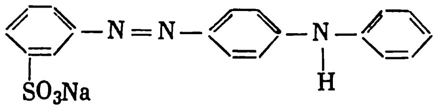
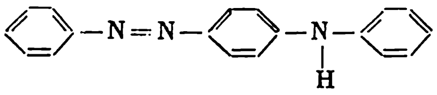
*For the use of the table, see p. 472.

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
6	Malachite green; first change (see No. 69)		0.1	Water	0.13-2.0 yellow — bluish green
7	Methyl violet (see Nos. 1 and 15; second change)	*See* No. 1	0.1	Water	1.0-1.5 green — blue
8	Metanil yellow (victoria yellow, tropeolin G)		0.1	Water	1.2-2.3 red — yellow
9	Benzene azodiphenylamine		0.01	50% alcohol with an addition of	1.1-2.8 purple — yellow

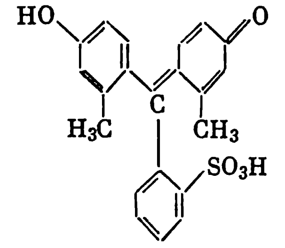
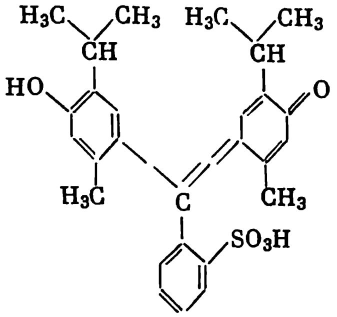
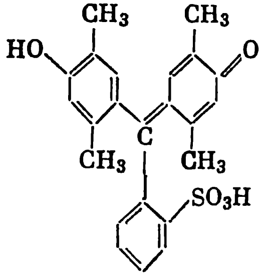
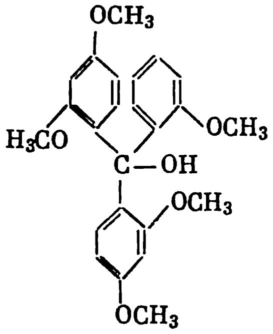
				1 ml of 1*N* HCl per 100 ml of solution	
10	*m*-Cresol purple (*m*-cresolsulphophthalein); first change, (see No. 50)		0.04	20% alcohol	1.2-2.8 red—yellow
11	Thymol blue (thymolsulphophthalein); first change (see No. 53)		0.1	(a) 20% alcohol; (b) water with an addition of 4.3 ml of 0.05*N* NaOH per 100 mg of the indicator	1.2-2.8 red—yellow λ_{max} 544-430 nm

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
12	Xylenol blue (*p*-xylenolsulphophthalein); first change (see No. 54)		0.04 0.05	(a) 20% alcohol; (b) water with an addition of 5.3 ml of 0.05*N* NaOH per 100 mg of the indicator	1.2-2.8 red—brown-yellow
13	Pentamethoxy red		0.1	70% alcohol	1.2-3.2 red-violet—colourless

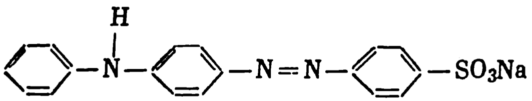
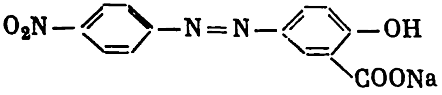
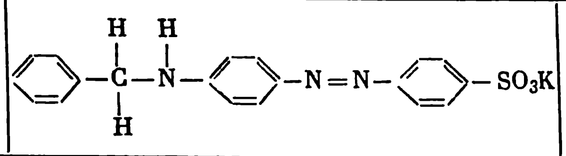
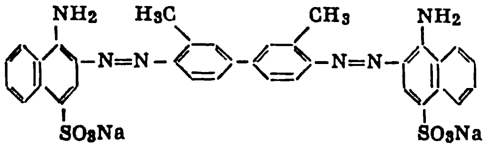
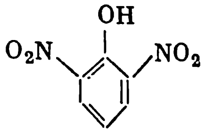
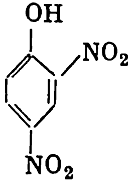
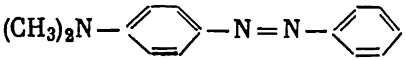
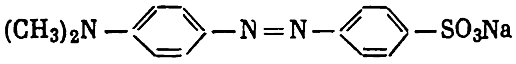
14	Tropeolin 00 (orange IV; diphenyl orange)		1.0, 0.1 and 0.01	Water	1.4-3.2 red—yellow
15	Methyl violet; third change (see Nos. 1 and 7)	*See* No. 1	0.1	Water	2.0-3.0 blue—violet
16	Alizarin Yellow R; first change		0.1	Water	1.9-3.3 red—yellow
17	Benzyl orange		0.05	Water	1.9-3.3 red—yellow
18	Benzopurpurin 4B; first change (see No. 74)		0.1 0.5	Water 90% alcohol	1.3-4.0 bluish violet—orange

Table 19 (*continued*)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
19	β-Dinitrophenol (2,6-dinitrophenol)		0.1; 0.05 and 0.04	Water	2.4-4.0 colourless—yellow
20	α-Dinitrophenol (2,4-dinitrophenol)		Saturated and 0.04 0.1	Water Alcohol	2.8-4.4 colourless—yellow
21	Methyl yellow (butter yellow)		0.1 and 0.01	90% alcohol	2.9-4.0 red—yellow
22	Methyl orange (Helianthine B; orange III)		0.1	Water	3.1-4.4 red—orange-yellow λ_{max} 522-464 nm

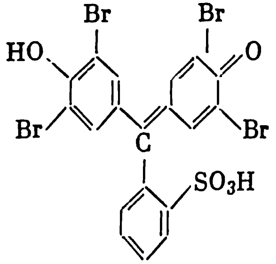
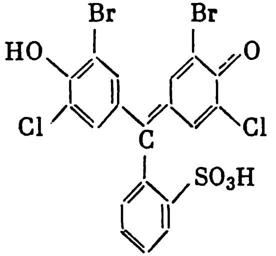
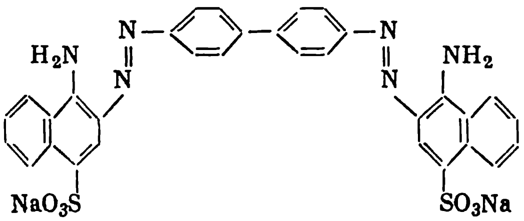
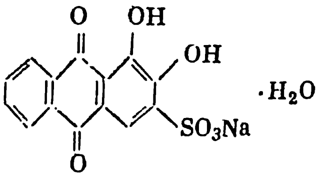
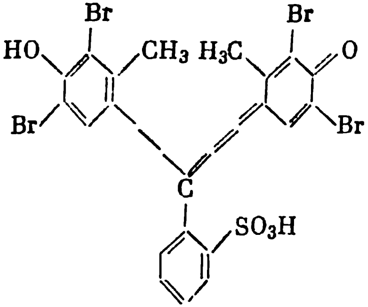
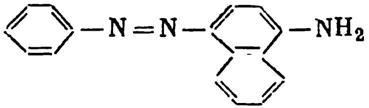
23	Bromophenol blue (tetrabromophenolsulphophthalein)		0.1	(a) 20% alcohol; (b) water with an addition of 3.0 ml of 0.05*N* NaOH per 100 mg of the indicator	3.0-4.6 yellow — blue λ_{max} 436-592 nm
24	Bromochlorophenol blue		0.04	(a) 20% alcohol (b) water with an addition of 3.2 ml of 0.05*N* NaOH per 100 mg of the indicator	3.0-4.8 yellow — purple
25	Congo red		0.1 and 1.0	Water	3.0-5.2 bluish violet — red

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
26	Alizarin Red S (Alizarin S, sodium alizarin sulphonate); first change (see No. 61)		0.1	Water	3.7-5.2 yellow—violet
27	Bromocresol blue (bromocresol green)		0.1	(a) 20% alcohol; (b) water with an addition of 2.9 ml of 0.05*N* NaOH per 100 mg of the indicator	3.8-5.4 yellow—blue λ_{max} 444-617 nm
28	α-Naphthyl red		0.1	70% alcohol	3.7-5.7 violet—brownish yellow

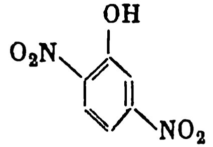
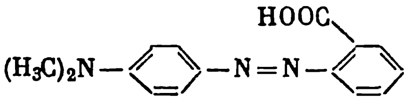
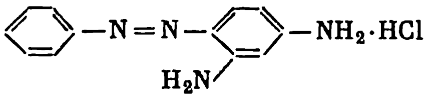
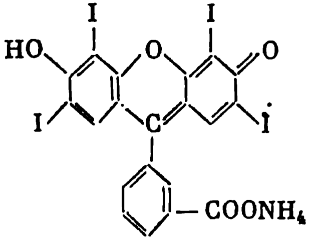
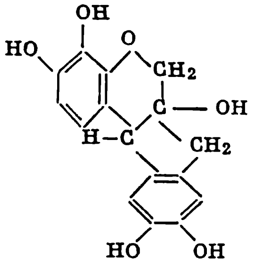
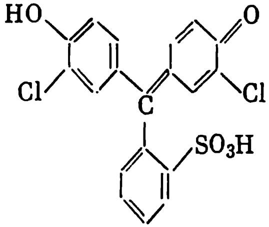
29	γ-Dinitrophenol (2,5-dinitrophenol)		0.1 and 0.025	Water	4.0-5.4 colourless—yellow
30	Lacmoid	$C_{12}H_9O_3N$	0.2 and 0.5	90% alcohol	4.0-6.4 red—blue
31	Methyl red		0.1 and 0.2	60% alcohol	4.2-6.2 red—yellow λ_{max} 530-427 nm
32	Chrysoidine		0.1	Water	4.0-7.0 orange—yellow
33	Iodeosin (tetraiodofluorescein)		0.1	Water (corresponding acid is dissolved in 70% alcohol)	4.5-6.5 colourless—red

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
34	Hematoxylin		0.5	90% alcohol	5.0-6.0 yellow—violet
35	Chlorophenol red (dichlorophenolsulphophthalein)		0.1	(a) 20% alcohol; (b) water with an addition of 4.7 ml of 0.05*N* NaOH per 100 mg of the indicator	5.0-6.6 yellow—red

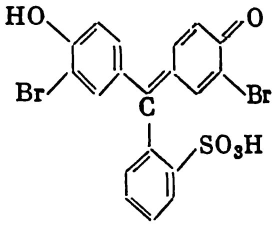
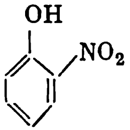
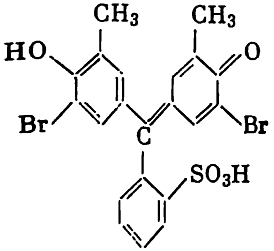
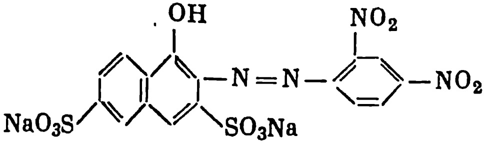
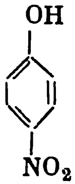
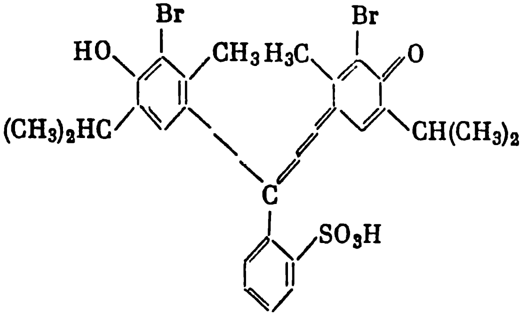
36	Bromophenol red (dibromophenolsulphophthalein)		0.1 and 0.04	(a) 20% alcohol; (b) water with an addition of 3.9 ml of 0.05*N* NaOH per 100 mg of the indicator	5.0-6.8 yellow—red
37	*o*-Nitrophenol		0.1	50% alcohol	5.0-7.0 colourless—yellow
38	Bromocresol purple (dibromine-*o*-cresolsulphophthalein)		0.1	(a) 20% alcohol; (b) water with an addition of 3.7 ml of 0.05*N* NaOH per 100 mg of the indicator	5.2-6.8 yellow—purple λ_{max} 433-591 nm

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
39	Nitrazine yellow		0.1	Water	6.0-7.0 yellow—blue-violet
40	*p*-Nitrophenol		0.1	Water	5.6-7.6 colourless—yellow
41	Bromothymol blue (dibromothymolsulphophthalein)		0.05 and 0.1	(a) 20% alcohol; (b) water with an addition of 3.2 ml of 0.05*N* NaOH per 100 mg of the indicator	6.0-7.6 yellow—blue λ_{max} 433-617 nm

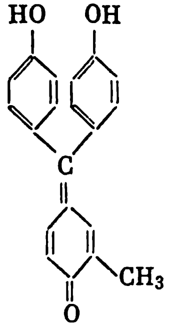
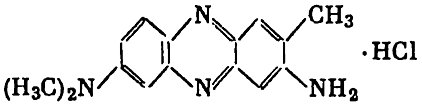
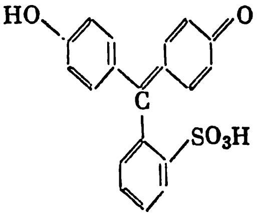
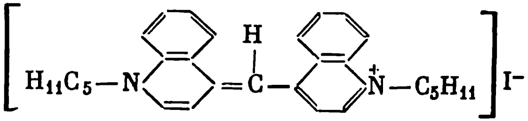
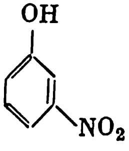
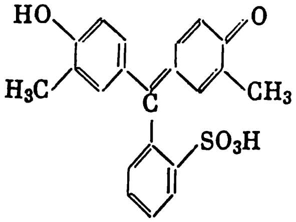
42	*p*-Rosolic acid (corallinophthalein; aurin; methylaurin; yellow coralline)		0.5 and 0.1	50% alcohol	6.2-8.0 yellow—red
43	Neutral red		0.1	60% alcohol	6.8-8.4 red—yellow-brown
44	Phenol red (phenolsulphophthalein)		0.1 and 0.05	(a) 20% alcohol; (b) water with an addition of 5.7 ml of 0.05N NaOH per 100 mg of the indicator	6.8-8.4 yellow—red λ_{max} 433-558 nm

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
45	Quinoline blue (cyanine)		1.0	90% alcohol	7.0-8.0 colourless—violet
46	*m*-Nitrophenol		0.3	Water	6.8-8.4 colourless—yellow
47	Cresol red (*o*-cresolsulphophthalein)		0.1	(a) 50% alcohol; (b) water with an addition of 5.3 ml of 0.05*N* NaOH per 100 mg of the indicator	7.2-8.8 amber yellow—purple red λ_{max} 434-572 nm

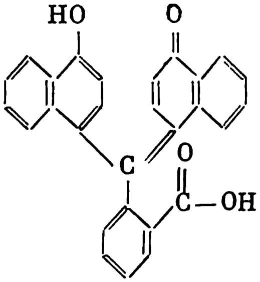
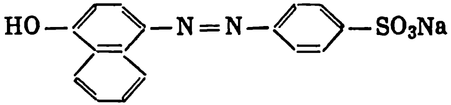
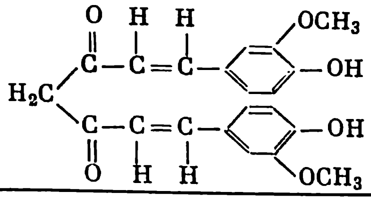
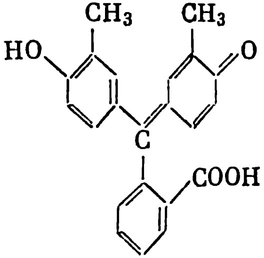
48	α-Naphtholphthalein		0.1 and 1.0	70% alcohol	7.4-8.6 yellow-pink—blue-green
49	Ethyl-bis-(2,4-dinitrophenyl)-acetate	—	0.1	Alcohol	7.4-9.0 colourless—blue
50	*m*-Cresol purple; second change (see No. 10)	*See* No. 10			7.4-9.0 yellow—purple
51	Tropeolin 000		0.1 and 1.0	Water	7.6-8.9 yellow-green—pink

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
52	Curcumin; first change		0.1	90% alcohol	7.4-9.2 yellow— brown-red
53	Thymol blue; second change (see No. 11)	*See* No. 11			8.0-9.6 yellow—blue λ_{max} 430-596 nm
54	Xylenol blue; second change (see No. 12)	*See* No. 12			8.0-9.6 yellow—blue
55	*o*-Cresolphthalein		0.2 and 0.02	90% alcohol	8.2-9.8 colourless—red

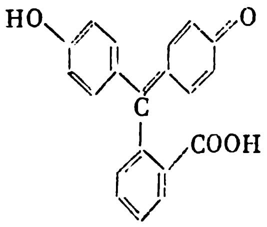
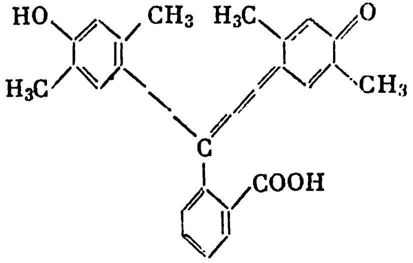
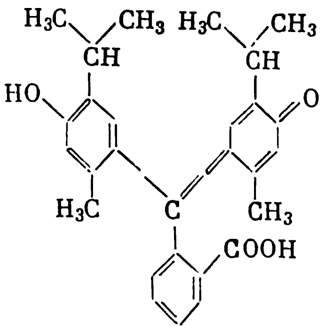
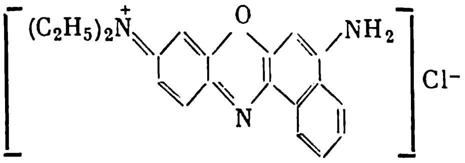
56	Phenolphthalein		0.1 and 1.0	60% alcohol	8.2-10.0 colourless—purple λ_{max} 553 nm
57	α-Naphtholbenzoin; second change (see No. 2)	*See* No. 2			8.4-10.0 yellow—blue
58	*p*-Xylenolphthalein		0.1	40% alcohol	9.3-10.5 colourless—blue

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
59	Thymolphthalein	 H₃C CH₃ H₃C CH₃ CH CH HO O H₃C C CH₃ COOH	0.1 0.04	90% alcohol 50% alcohol	9.3-10.5 colourless—blue λ_{max} 598 nm
60	Nile blue		0.1	Water	10.1-11.1 blue—red
61	Alizarin Red S; second change (see No. 26)	*See* No. 26			10.0-12.0 violet—pale yellow

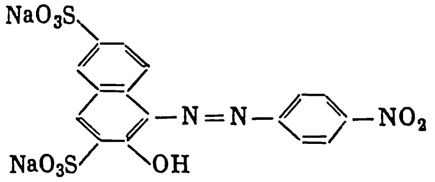
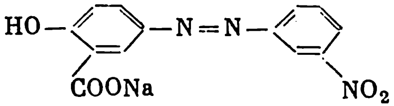
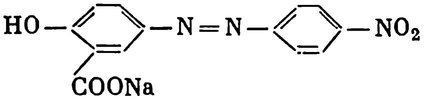
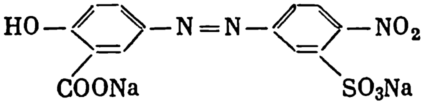
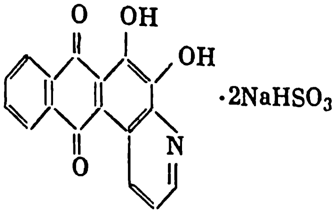
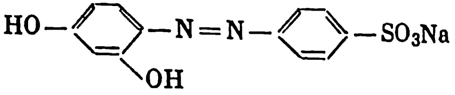
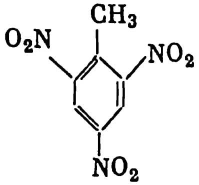
62	Curcumin; second change (see No. 52)	*See* No. 52			10.2-11.8 brown-red—orange-yellow
63	β-Naphthol violet		0.04	Water	10.0-12.1 orange-yellow—violet
64	Alizarin Yellow GG (salicyl yellow; mordant yellow)		0.1	Water	10.0-12.1 light yellow—dark orange
65	Alizarin Yellow R		0.1	Water.	10.1-12.1 yellow—lilac
66	Alizarin Yellow RS		0.1	Water	10.1-12.1 light yellow—brown-red

Table 19 (continued)

No.	Indicator	Formula	Concentration, %	Solvent	pH range and the indicator colour
67	Alizarin Blue BS		0.05	Water	11.0-13.0 orange-yellow — green-blue
68	Tropeolin 0 (gold yellow; chrysoine; resorcinol yellow)		0.1	Water	11.0-13.0 yellow—orange-brown
69	Malachite green; second change (see No. 6)	*See* No. 6			11.5-13.2 bluish green — colourless
70	2,4,6-Trinitrotoluene		0.1 and 0.5	90% alcohol	11.5-13.2 colourless — orange

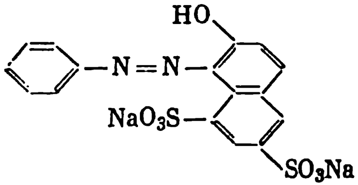
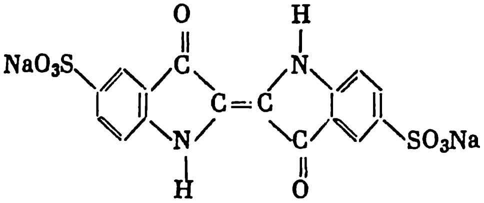
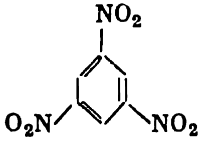
71	Orange G		0.1	Water	11.5-14.0 yellow—red
72	Indigo carmine (sodium indigo disulphonate)		0.25	50% alcohol	11.6-14.0 blue—yellow
73	1,3,5-Trinitrobenzene		0.1 and 0.5	90% alcohol	12.2-14.0 colourless—orange
74	Benzopurpurin 4B; second change (see No. 18)	*See* No. 18			13.0-14.0 orange—red

Table 20

Ionic Product of Water at Temperatures Ranging from 0 °C to 100 °C

$$K_w = a_{H^+} \times a_{OH^-} \qquad \sqrt{K_w} = a_{H^+} = a_{OH^-}$$

t, °C	K_w	$\sqrt{K_w}$
0	$10^{-14.96} = 0.11 \times 10^{-14}$	$10^{-7{,}48} = 0.33 \times 10^{-7}$
5	$10^{-14.76} = 0.17 \times 10^{-14}$	$10^{-7.38} = 0.42 \times 10^{-7}$
10	$10^{-14.53} = 0.30 \times 10^{-14}$	$10^{-7.27} = 0.54 \times 10^{-7}$
15	$10^{-14.34} = 0.46 \times 10^{-14}$	$10^{-7.17} = 0.68 \times 10^{-7}$
16	$10^{-14.30} = 0.50 \times 10^{-14}$	$10^{-7.15} = 0.71 \times 10^{-7}$
17	$10^{-14.26} = 0.55 \times 10^{-14}$	$10^{-7.13} = 0.74 \times 10^{-7}$
18	$10^{-14.22} = 0.60 \times 10^{-14}$	$10^{-7.11} = 0.77 \times 10^{-7}$
19	$10^{-14.19} = 0.65 \times 10^{-14}$	$10^{-7.10} = 0.80 \times 10^{-7}$
20	$10^{-14.16} = 0.69 \times 10^{-14}$	$10^{-7.08} = 0.83 \times 10^{-7}$
21	$10^{-14.12} = 0.76 \times 10^{-14}$	$10^{-7.06} = 0.87 \times 10^{-7}$
22	$10^{-14.09} = 0.81 \times 10^{-14}$	$10^{-7.05} = 0.89 \times 10^{-7}$
23	$10^{-14.06} = 0.87 \times 10^{-14}$	$10^{-7.03} = 0.93 \times 10^{-7}$
24	$10^{-14.03} = 0.93 \times 10^{-14}$	$10^{-7.02} = 0.96 \times 10^{-7}$
25	$10^{-14.00} = 1.00 \times 10^{-14}$	$10^{-7.00} = 1.00 \times 10^{-7}$
26	$10^{-13.96} = 1.10 \times 10^{-14}$	$10^{-6.98} = 1.05 \times 10^{-7}$
27	$10^{-13.93} = 1.17 \times 10^{-14}$	$10^{-6.97} = 1.07 \times 10^{-7}$
28	$10^{-13.89} = 1.29 \times 10^{-14}$	$10^{-6.95} = 1.12 \times 10^{-7}$
29	$10^{-13.86} = 1.38 \times 10^{-14}$	$10^{-6.93} = 1.17 \times 10^{-7}$
30	$10^{-13.83} = 1.48 \times 10^{-14}$	$10^{-6.92} = 1.20 \times 10^{-7}$
31	$10^{-13.80} = 1.58 \times 10^{-14}$	$10^{-6.90} = 1.26 \times 10^{-7}$
32	$10^{-13.77} = 1.70 \times 10^{-14}$	$10^{-6.89} = 1.29 \times 10^{-7}$
33	$10^{-13.74} = 1.82 \times 10^{-14}$	$10^{-6.87} = 1.35 \times 10^{-7}$
34	$10^{-13.71} = 1.95 \times 10^{-14}$	$10^{-6.86} = 1.38 \times 10^{-7}$
35	$10^{-13.68} = 2.09 \times 10^{-14}$	$10^{-6.84} = 1.45 \times 10^{-7}$
36	$10^{-13.65} = 2.24 \times 10^{-14}$	$10^{-6.83} = 1.48 \times 10^{-7}$
37	$10^{-13.62} = 2.40 \times 10^{-14}$	$10^{-6.81} = 1.55 \times 10^{-7}$
38	$10^{-13.59} = 2.57 \times 10^{-14}$	$10^{-6.80} = 1.58 \times 10^{-7}$
39	$10^{-13.56} = 2.75 \times 10^{-14}$	$10^{-6.78} = 1.66 \times 10^{-7}$
40	$10^{-13.53} = 2.95 \times 10^{-14}$	$10^{-6.77} = 1.70 \times 10^{-7}$
50	$10^{-13.26} = 5.50 \times 10^{-14}$	$10^{-6.63} = 2.34 \times 10^{-7}$
60	$10^{-13.02} = 9.55 \times 10^{-14}$	$10^{-6.51} = 3.09 \times 10^{-7}$
70	$10^{-12.80} = 15.8 \times 10^{-14}$	$10^{-6.40} = 3.98 \times 10^{-7}$
80	$10^{-12.60} = 25.1 \times 10^{-14}$	$10^{-6.30} = 5.01 \times 10^{-7}$
90	$10^{-12.42} = 38.0 \times 10^{-14}$	$10^{-6.21} = 6.17 \times 10^{-7}$
100	$10^{-12.26} = 55.0 \times 10^{-14}$	$10^{-6.13} = 7.41 \times 10^{-7}$

Table 21

Colorimetric Determination of the pH of Solutions*

Salt corrections for the most important indicators at different ionic strength of a solution (Ionic strength of the reference buffer solutions used is equal to 0.1)

Indicator	Ionic strength							
	0.0025	0.005	0.01	0.02	0.05	0.1	0.5 (KCl)	0.5 (NaCl)
	Salt correction							
Bromocresol blue (bromocresol green)	+0.21	+0.18	+0.16	+0.14	+0.05	0.00	—0.12	—0.16
Bromophenol blue	+0.15	+0.14	+0.14	+0.13	+0.10	0.00	—0.10	—0.18
Bromothymol blue	+0.14	+0.12	+0.11	+0.07	+0.04	0.00	—0.20	—0.28
Chlorophenol red	—	+0.15	+0.13	+0.12	+0.05	0.00	—0.16	—0.19
Methyl orange	—0.04	—0.04	—0.02	0.00	0.00	0.00	0.00	0.00
Methyl red	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phenol red	+0.14	+0.12	+0.11	+0.07	+0.04	0.00	—0.20	—0.29
Phenolphthalein	—	+0.18	+0.12	+0.10	+0.05	0.00	—0.16	—0.21
Thymol blue; first change	—	—	0.00	0.00	0.00	0.00	0.00	0.00
Thymol blue; second change	—	+0.16	+0.12	+0.09	+0.05	0.00	—0.12	—0.19
Thymolphthalein	—	—	+0.11	+0.09	+0.05	0.00	—0.19	—

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* For the use of the table, see p. 473.

Table 22

Ionization Constants of Indicators (pK_1; at different ionic strength)

(t = temperature of experiment)

A. Monochromatic Indicators

Indicator	pK_1 (at a zero ionic strength and different temperatures) $A = t - 20\,°C$	pK_1 ($t = 20\,°C$) Ionic strength, μ			
		0.01	0.05	0.1	0.5
Pentamethoxy red	$1.86 + 0.008\,A$	—	1.86	1.86	—
Quinaldine red	$2.63 - 0.007\,A$	2.80	—	2.90	3.10
α-Dinitrophenol	$4.10 - 0.006\,A$	—	3.95	3.90	3.80 (KCl)
β-Dinitrophenol	$3.70 - 0.006\,A$	—	3.95	3.90	3.80 (KCl)
γ-Dinitrophenol	$5.20 - 0.0045\,A$	—	5.12	5.10	5.00 (NaCl)
p-Nitrophenol	$7.00 - 0.011\,A$	—	—	—	—
m-Nitrophenol	$8.35 - 0.01\,A$	—	8.30	8.25	8.15 (NaCl)

B. Dichromatic Indicators

Indicator	pK_1 (Ionic strength = =0)	pK_1 ($t = 20\,°C$) Ionic strength, μ			
		0.01	0.05	0.1	0.5
Thymol blue (acid region)*	1.65 (15-30 °C)	—	1.65	1.65	1.65
Methyl orange*	$3.46 - 0.014$ ($t = 20\,°C$)	3.46	3.46	3.46	3.46
Bromophenol blue	4.10 (15-20 °C)	4.06	4.00	3.85	3.75 (KCl)
Bromocresol blue (bromocresol green)	4.90 (15-30 °C)	4.80	4.70	4.66	4.50 (KCl) 4.42 (NaCl)
Methyl red* . . .	$5.00 - 0.006$ ($t = 20\,°C$)	5.00	5.00	5.00	5.00
Chlorophenol red	$6.25 - 0.005$ ($t = 20\,°C$)	6.15	6.05	6.00	5.9 (KCl) 5.85 (NaCl)
Bromocresol purple	$6.40 - 0.005$ ($t = 20\,°C$)	6.28	6.21	6.12	5.9 (KCl) 5.8 (NaCl)
Bromothymol blue	7.30 (15-30 °C)	7.19	7.13	7.10	6.9 (KCl) 6.8 (NaCl)
Phenol red	$8.00 - 0.007$ ($t = 20\,°C$)	7.92	7.84	7.81	7.6 (KCl) 7.5 (NaCl)
Thymol blue . . .	9.20 (15-30 °C)	9.01	8.95	8.90	—

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* Methyl orange. methyl red and thymol blue (acid region) have an advantageous feature, i.e., their constants are scarcely affected by the electrolytes present, up to an ionic strength of 0.5.

Table 23

Some Mixed Indicators*

Titration index pT is the pH value whereby the observer clearly sees the change in the indicator's colour and recognizes titration as complete. This is a somewhat conditional quantity which differs from person to person who performs titration.

Titration index (pT)	Components	Ratio of volumes	Indicator colour	
			In acidic medium	In alkaline medium
3.25	Methyl yellow, 0.1% solution in alcohol Methylene blue, 0.1% solution in alcohol	1 : 1	Blue-violet	Green
4.1	Methyl orange, 0.1% solution in water Indigo carmine, 0.25% solution in water	1 : 1	Violet	Green
4.3	Bromocresol blue, sodium salt, 0.1% solution in water Methyl orange, 0.2% solution in water	1 : 1	Yellow	Blue-green
5.1	Bromocresol blue, 0.1% solution in alcohol Methyl red, 0.2% solution in alcohol	3 : 1	Wine red	Green
5.4	Methyl red, 0.2% solution in alcohol Methylene blue, 0.1% solution in alcohol	1 : 1	Red-violet	Green
6.1	Bromocresol blue, sodium salt, 0.1% solution in water Chlorophenol red, sodium salt, 0.1% solution in water	1 : 1	Yellow-green	Blue-violet

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* Indicators are kept in flasks of dark glass.

Table 23 (continued)

Titration index (pT)	Components	Ratio of volumes	Indicator colour	
			in acidic medium	in alkaline medium
6.7	Bromocresol purple, sodium salt, 0.1% solution in water Bromothymol blue, sodium salt, 0.1% solution in water	1 : 1	Yellow	Blue-violet
7.0	Neutral red, 0.1% solution in alcohol Methylene blue, 0.1% solution in alcohol	1 : 1	Violet-blue	Green
7.2	Neutral red, 0.1% solution in alcohol Bromothymol blue, 0.1% solution in alcohol	1 : 1	Pink	Green
7.5	Bromothymol blue, sodium salt, 0.1% solution in water Phenol red, sodium salt, 0.1% solution in water	1 : 1	Yellow	Violet
8.3	Cresol red, sodium salt, 0.1% solution in water Thymol blue, sodium salt, 0.1% solution in water	1 : 3	Yellow	Violet
8.9	α-Naphtholphthalein, 0.1% solution in alcohol Phenolphthalein, 0.1% solution in alcohol	1 : 3	Pale pink	Violet
9.0	Thymol blue, 0.1% solution in 50% alcohol Phenolphthalein, 0.1% solution in 50% alcohol	1 : 3	Yellow	Violet
9.9	Phenolphthalein, 0.1% solution in alcohol Thymolphthalein, 0.1% solution in alcohol	1 : 1	Colourless	Violet
10.2	Thymolphthalein, 0.1% solution in alcohol Alizarin yellow, 0.1% solution in alcohol	2 : 1	Yellow	Violet

Table 24

Universal Indicators

1. 100 mg of phenolphthalein, 200 mg of methyl red, 300 mg of methyl yellow, 400 mg of bromothymol blue and 500 mg of thymol blue are dissolved in 500 ml of 96% alcohol, then 0.1 N solution of caustic soda is added until the appearance of a pure yellow colour (pH 6).

Colour . .	Red	Orange	Yellow	Green	Blue
pH . . .	2.0	4.0	6.0	8.0	10.0

2. 15 ml of 0.1% solution of methyl yellow, 5 ml of 0.1% solution of methyl red, 20 ml of 0.1% solution of bromothymol blue, 20 ml of 0.1% solution of phenolphthalein and 20 ml of 0.1% solution of thymolphthalein are mixed.

Colour	Pink	Red-orange	Orange
pH	1.0	3.0	4.0
Colour	Yellow-orange	Lemon yellow	Yellow-green
pH	5.0	6.0	7.0
Colour	Green	Blue-green	Violet
pH	8.0	9.0	10.0

3. 70 mg of tropeolin 00, 100 mg of methyl orange, 80 mg of methyl red, 400 mg of bromothymol blue, 500 mg of phenolphthalein and 100 mg of alizarin yellow R are dissolved in 100 ml of 50% alcohol.

Colour	Orange-red	Red-orange	Orange
pH	2.0	3.0	4.0
Colour	Yellow-orange	Orange-yellow	Yellow
pH	5.0	6.0	6.5
Colour	Green-yellow	Green	Green-blue
pH	7.0	8.0	9.0
Colour	Blue-violet	Violet	Red-violet
pH	9.5	10.0	12.0

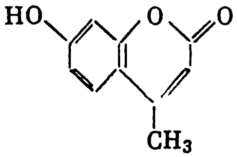
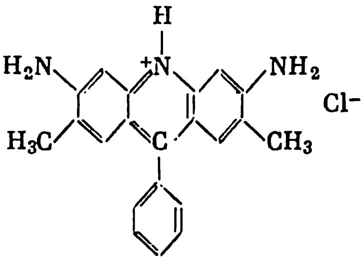
4. 100 mg of methyl red, 100 mg of bromothymol blue, 100 mg of α-naphtholphthalein, 100 mg of phenolphthalein and 100 mg of thymolphthalein are dissolved in 500 ml of 96% alcohol.

Colour . .	Red	Orange	Yellow	Green-yellow
pH	4.0	5.0	6.0	7.0
Colour	Green	Blue-green	Blue-violet	Red-violet
pH	8.0	9.0	10.0	11.0

Table 25

Chief Fluorescent Indicators

(in the order of the growth of the pH of fluorescence change)

No.	Indicator	Formula	pH range	Change in fluorescence
1	β-Methylumbelliferone (4-methylumbelliferone; 7-hydroxy-4-methylcoumarin); first change (see No. 18)		0.0-2.0	Green—pale blue
2	Benzoflavin		0.3-1.7	Yellow—green

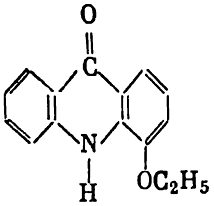
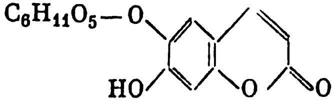
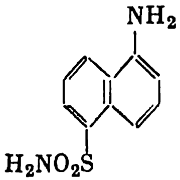
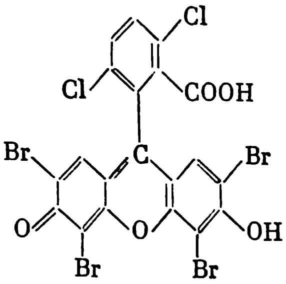
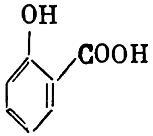
3	4-Ethoxyacridone		1.4-3.2	Green—blue
4	Esculin		1.5-2.0	Absence—blue
5	1,5-Naphthylaminesulphamide; first change		2.0-4.0	Intensification of yellow-orange fluorescence

Table 25 (continued)

No.	Indicator	Formula	pH range	Change in fluorescence
6	Phloxine (3′, 6′-dichloro-2, 4, 5, 7-tetrabromofluorescein)		2.0-4.0	Absence—yellow-orange
7	Salicylic acid		2.5-3.5	Intensification of blue fluorescence

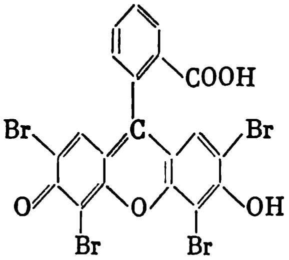
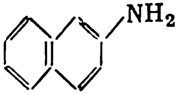
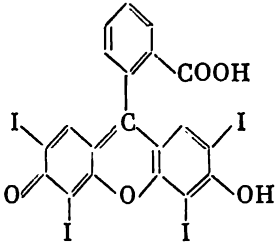
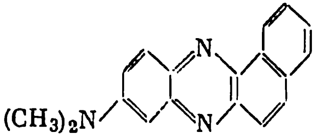
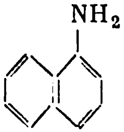
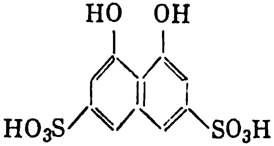
8	Eosine (tetrabromofluorescein)		2.5-4.5	Intensification of yellow-green fluorescence
9	β-Naphthylamine (2-naphthylamine)		2.8-4.4	Intensification of violet fluorescence
10	Erythrosine (tetraiodofluorescein)		3.0-4.2	Intensification of blue-green fluorescence

Table 25 (continued)

No.	Indicator	Formula	pH range	Change in fluorescence
11	Dimethylnaphtheirhodine		3.2-3.8	Lilac—orange
12	α-Naphthylamine (1-naphthylamine); first change (see No. 32)		3.4-4.8	Intensification of blue fluorescence
13	Chromotropic acid		3.5-6.0	Intensification of blue fluorescence

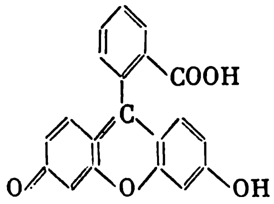
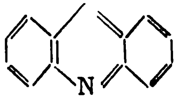
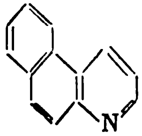
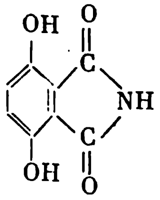
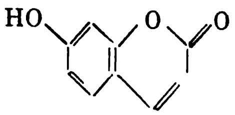
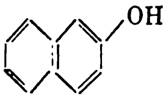
14	Fluorescein		4.0-5.0	Intensification of green fluorescence
15	Quinic acid	$C_6H_7(OH)_4COOH$	4.0-5.0	Yellow—blue
16	Quinine; first change (see No. 28)	$C_{20}H_{24}O_2N_2$	3.8-6.1	Blue—violet
17	Acridine		4.8-6.6	Green—violet-blue
18	β-Methylumbelliferone; second change (see No. 1)	*See* No. 1	5.0-7.6	Intensification of blue fluorescence
19	β-Naphthoquinoline		5.0-8.0	Brilliant blue—pale violet

Table 25 (*continued*)

No.	Indicator	Formula	pH range	Change in fluorescence
20	3,6-Dioxyphthalimide		6.0-8.0	Green—yellow-green
21	Umbelliferone		6.5-7.6	Absence—blue
22	β-Naphthol (2-naphthol)		7.0-8.5	Pale blue—blue-violet

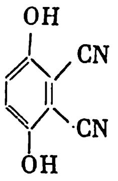
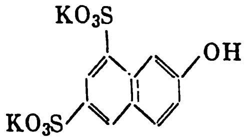
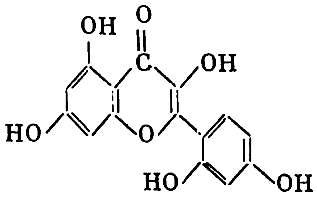
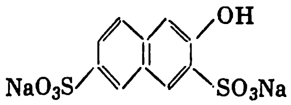
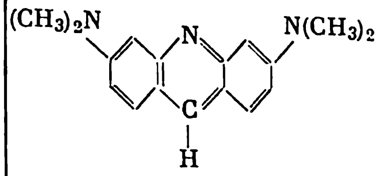
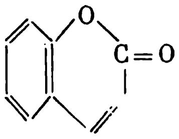
23	2,3-Dicyanhydroquinone		6.8-8.8	Blue—green
24	G-Salt		7.4-9.0	Intensification of blue fluorescence
25	Morin (3, 5, 7, 2′, 4′-pentaoxyflavone)		7.0-10.0	Green—yellow
26	R-Salt		8.0-10.6	Intensification of blue fluorescence

Table 25 (continued)

No.	Indicator	Formula	pH range	Change in fluorescence
27	Euchrysine 3R (base of acridine orange)		8.4-10.4	Orange—green
28	Quinine; second change (see No. 16)	*See* No. 16	9.5-10.5	Violet—absence
29	1,5-Naphthylaminesulphamide; second change (see No. 5)	*See* No. 5	9.5-13.0	Yellow-orange—green
30	Coumarin		9.8-12.0	Dark green—light yellow

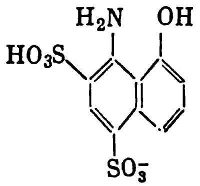
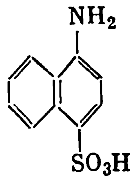
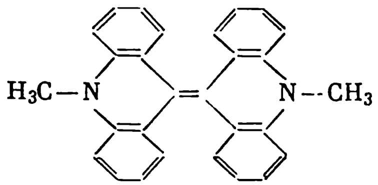
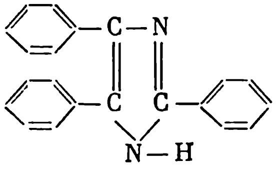
31	SS-Acid		10.0-12.0	Violet—green
32	α-Naphthylamine; second change (see No. 12)	*See* No. 12	12.0-13.0	Weakening of blue fluorescence
33	Naphthionic acid		11.5-14.0	Violet-blue—bluish green

Table 26

Selected Chemiluminescent Indicators

Indicator	Formula	pH at which luminescence occurs
N, N′-Dimethylbiacridene		~9
Lophine (2, 4, 5-Triphenylimidazole; 2, 4, 5-triphenylglyoxaline		8.9-9.4

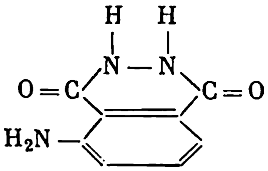
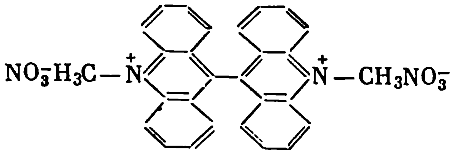
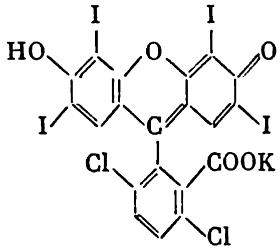
Luminol		8.0-8.5
Lucigenin		9.0-10.0

Table 27

Principal Adsorption Indicators

No.	Indicator	Formula	Ion of titrating reagent	Ion being determined	Change in colour
1	Alizarin Red S (0.4% aqueous solution)	*See* Table 19, No. 26 (p. 184)	Pb^{2+}	$Fe(CN)_6^{4-}$	Yellow—pink-red
2	Bengali pink (3′, 6′-dichloro-2, 4, 5, 7-tetraiodofluorescein, potash salt) (0.5% aqueous solution)		Ag^+	I^-	Pink—violet
3	Bromocresol blue (bromocresol green) (1% solution in 20% alcohol)	*See* Table 19, No. 27 (p. 184)	Ag^+	Cl^-	Violet—greenish blue
4	Bromophenol blue (0.1% alcohol solution or 0.1% aqueous solution of sodium salt)	*See* Table 19, No. 23 (p. 183)	Ag^+	Cl^-, Br^-, SCN^- I^-	Yellow—blue Yellow-green—blue-green

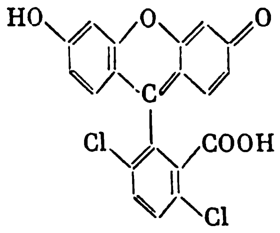
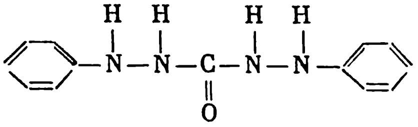
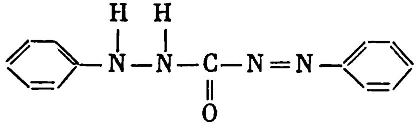
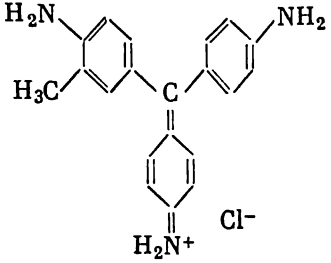
5	Congo red (0.1% aqueous solution)	*See* Table 19, No. 25 (p. 183)	Ag^+	Cl^-, Br^-, I^-	Red—blue
6	3,6-Dichlorofluorescein (0.1% solution in 60-70% alcohol, or 0.1% solution of sodium salt in water)		Ag^+	Cl^-, Br^-	Red-violet—blue-violet
					SCN^-	Pink—red-violet
				I^-	Yellow-green—orange
7	Diphenylcarbazide		Hg_2^{2+}	Cl^-, Br^-	Colourless—violet
8	Diphenylcarbazone (0.2% alcohol solution)		Ag^+	Cl^-	Light red—violet
				Br^-, I^-	Yellow—green
				SCN^-	Pink—blue

Table 27 (continued)

No.	Indicator	Formula	Ion of titrating reagent	Ion being determined	Change in colour
9	Eosine (0.5% solution of sodium salt in water or 0.1% solution of eosine in 60-70% alcohol)	*See* Table 25, No. 8 (p. 207)	Ag^+	Br^-, I^-, SCN^-	Orange—intense red
10	Erythrosine (0.5% aqueous solution)	*See* Table 25, No. 10 (p. 207)	Pb^{2+}	MoO_4^{2-}	Orange—dark red
11	Fluorescein (0.1% alcohol solution)	*See* Table 25, No. 14 (p. 209)	Ag^+	Cl^-, Br^-, SCN^- I^-	Yellow-green—pink Yellow-green—orange
12	Fuchsin (0.1% alcohol solution)		Ag^+	Cl^- Br^-, I^- SCN^-	Red-violet—pink Orange—pink Bluish—pink

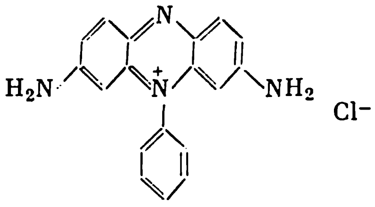
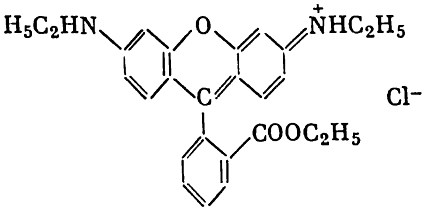
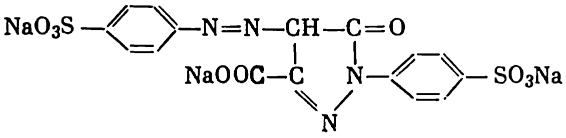
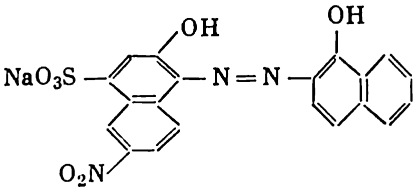
13	Phenosafranine (0.1% aqueous solution)		Ag^+	Cl^- Br^-	Violet—pink Red-violet—blue
14	Rhodamine 6G (0.1% aqueous solution)		Ag^+	Br^-, Cl^-	Red-violet—orange
15	Tartrazine		Ag^+	Cl^-, Br^-, I^-, SCN^-	Yellow-green—yellow-brown
16	Tropeolin 00 (1% aqueous solution)	*See* Table 19, No. 14 (p. 181)	Ag^+	Cl^-	Yellow—pink

Table 28

Indicators Commonly Used in Complexonometry

No.	Indicator	Formula
1	Acid Chrome Black Special (Chrome Black Special ET 00; Eriochrome Black T)	

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* RE stands for rare-earth elements, lanthanoids.

	Concentration	Ions being determined *	Conditions of determination	Change in colour
	Mixture of indicator (1 wt. %) and solid sodium chloride	Al^{3+}	pH 7-8; back titration with a zinc salt solution in the presence of pyridine	Wine red—blue
		Ba^{2+}	pH 10; titration in the presence of magnesium complexonate	
		Bi^{3+}	pH 9-10; back titration with a zinc salt solution	
		Ca^{2+}	pH 10; addition of magnesium complexonate	
		Cd^{2+}, Co^{3+}, Mg^{2+}, Zn^{2+}	pH 10	
		Cr^{3+}	Alkaline medium; back titration with a manganese salt solution	
		Fe^{3+}, Ti^{IV}	Back titration with a zinc salt solution in the presence of pyridine	
		Ga^{3+}	pH 6.5-9.5; back titration with a zinc salt solution	
		Hg^{2+}	pH 9-10; addition of magnesium complexonate	
		In^{3+}	pH 8-10; in the presence of potassium-sodium tartrate	
		Mn^{2+}	pH 10; addition of hydroxylamine	

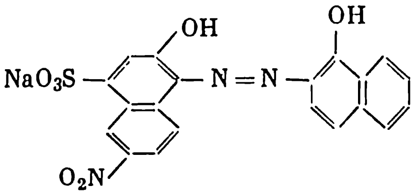
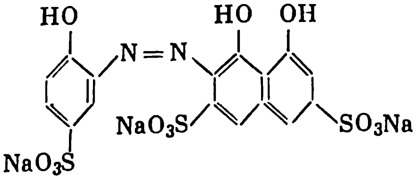
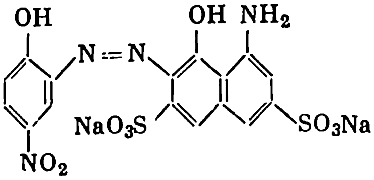
No.	Indicator	Formula
1	Acid Chrome Black Special (Chrome Black Special ET 00; Eriochrome Black T)	
2	Acid Chrome Blue K	
3	Acid Chrome Dark Green G (palatine chrome green)	
4	Alizarin Red S	*See* Table 19, No. 26 (p. 184)

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
Mixture of indicator (1 wt. %) and solid sodium chloride	Ni^{2+}, Pb^{2+}	pH 10; back titration with a magnesium salt or a zinc salt solution	Wine red—blue
	Tl^{3+}	pH 10; back titration with a magnesium salt solution or an addition of magnesium complexonate	
	V^{IV}	pH 10; back titration with a manganese salt solution	
Aqueous solution	Ca^{2+}	pH 12	Pink—gray-blue
	Mg^{2+}	pH 10-11; ammonia buffer	
	Cd^{2+}, Zn^{2+}	pH 9-10; ammonia buffer	
	Mn^{2+}	pH 10; ammonia buffer	
	Pb^{2+}	pH 10; in the presence of tartrate	
0.5% aqueous solution	Ca^{2+}	pH $>$ 12. Used in mixture with 0.25% aqueous solution of naphthol yellow in the ratio of 1 : 2 (hydrone II)	Brownish orange—green
	Ga^{3+}	pH 3	Blue—pink
0.05% aqueous solution	Th^{IV}, RE	pH 2.2-3.4	Pink—yellow
	Sc^{3+}	pH 2	
	Al^{3+}	pH 3.5-3.6; back titration with a thorium nitrate solution	Yellow—pink

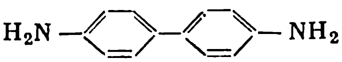
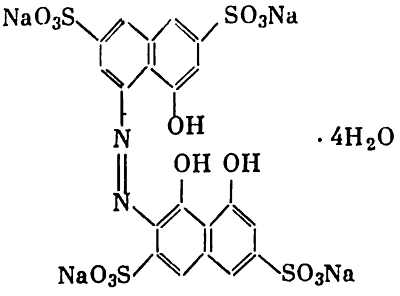
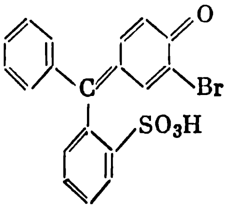
No.	Indicator	Formula
5	Arsenazo I	*See* Table 49, No. 7 (p. 362)
6	Benzidine	
7	Beryllon II	
8	Bromopyrogallol red, BPR	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
—	Pu^{IV} Th^{IV} U^{IV} RE Ca^{2+}, Mg^{2+}	0.1-0.2*M* HCl pH 1.6-3 pH 1.7 pH 7 pH 10	Violet—pink
1% solution in glacial acetic acid	Al^{3+}, Bi^{3+}, Fe^{3+}, Ga^{3+}, Sn^{IV}, Ti^{IV}	Buffer solution: 500 g of ammonium acetate and 20 ml of glacial acetic acid in one litre. Addition of $Fe(CN)_6^{4-}$ and $Fe(CN)_6^{3-}$, and back titration with a zinc acetate solution	Colourless—blue
0.02% aqueous solution	Be^{2+} Mg^{2+}	pH 12-13.2 pH 10	Blue—violet Blue-violet—violet-red
0.5% solution in 50% alcohol	Bi^{3+} Pb^{2+} Ni^{2+}, Co^{2+}, Cd^{2+} Mg^{2+}, Mn^{2+} Pd^{2+}, Tl^{3+}, Fe^{3+}, In^{3+}, Ga^{3+}	pH 2-3; HNO_3 pH 5-6 pH 9.3; ammonia buffer pH 10; ammonia buffer Back titration with a lead salt or a bismuth salt solution	Red—orange-yellow Blue-violet—red Blue—wine red Blue—violet-red

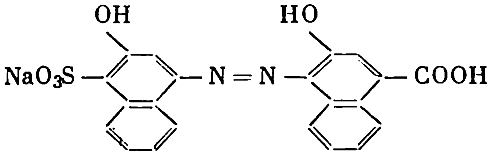
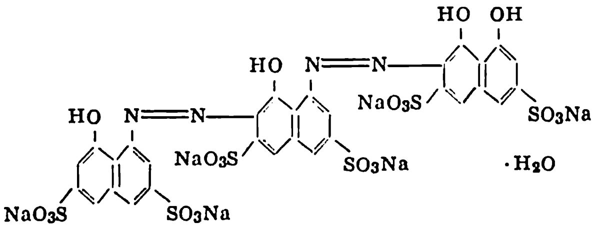
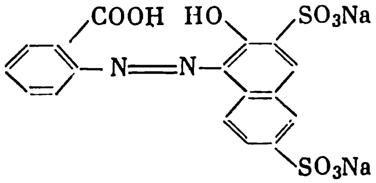
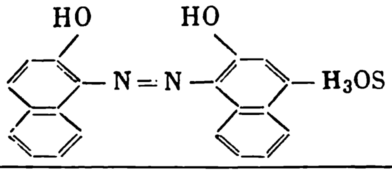
No.	Indicator	Formula
9	Calcein: *see* Fluorexone, No. 24 (p. 232)	
10	Calces (Patton-Reeder Dye; HHSNN)	
11	Calcion	
12	Calcon (Acid Alizarin Red V; Eriochrome Red RE)	
13	Chalcone (Eriochrome Blue-Black R; Erio R)	

Table 28 (continued)

	Concentration	Ions being determined	Conditions of determination	Change in colour
	Mixture of indicator (1 wt. %) and solid sodium chloride	Ca^{2+}	pH 12-14	Wine red—blue
	—	Ca^{2+}	pH > 12	Crimson—brilliant blue
	0.35% aqueous solution (10 ml) with the addition of 0.02% aqueous solution of methylene blue (10 ml), 0.4% solution of potassium salt (calculated on the basis of Ca^{2+}) (5 ml) and water (25 ml)	Ca^{2+}	pH 13	Yellow—orange-red
	—	Ca^{2+}	pH 14.5; NH_3; pH 12.5-13; NaOH	Pink—blue
		Cd^{2+}	pH 11.5; NH_3	
		Mg^{2+}, Mn^{2+}, Zn^{2+}	pH 10; ammonia buffer	

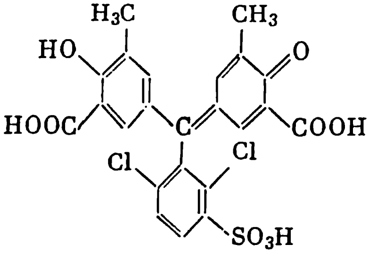
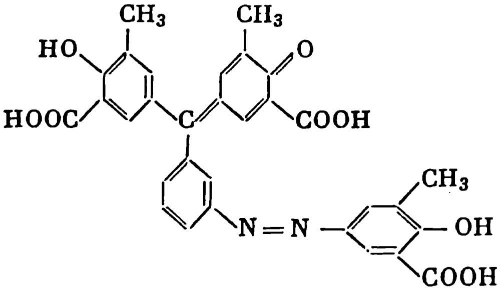
No.	Indicator	Formula
14	Chromasurol S (Eriochromasurol S; alberone)	
15	Chromogen Black Special ET 00: *See* Acid Chrome Black Spe-	
16	Chromoxane Green GG	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
0.4% aqueous solution	Al^{3+}	pH 4; acetate buffer, 80 °C	Violet—yellow-orange
	Ca^{2+}	pH 11; NH_3	Pale red-orange—yellow
	Cu^{2+}	pH 6-6.5; acetate buffer	Blue or blue-violet—green
		pH 8-10; NH_3	Violet—yellow or yellow-green
	Fe^{3+}	pH 2-3; chloroacetic-acetate buffer, 60 °C	Greenish blue—yellow-orange
	Mg^{2+}	pH 11; NH_3	Dirty red—yellow
	Ni^{2+}	pH 11; NH_3	Blue-violet—yellow
	RE^{3+}	pH 8; pyridine + $+NH_3$	Violet—yellow
	Th^{IV}	pH 1-3; HNO_3	Red-violet—orange
	VO^{2+}	pH 4; acetate buffer	Blue-violet—red-orange
cial, No. 1 (p. 220)			
—	Mg^{2+}, Ca^{2+}	pH 11	Red—green
	Cu^{2+}	pH 8	Red—orange
	Ni^{2+}	pH 11	Red—green
	Th^{IV}	pH 4.8	Violet—red
	VO^{2+}	pH 4	

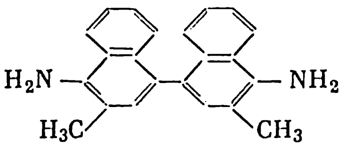
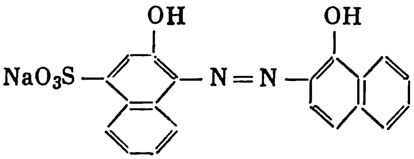
No.	Indicator	Formula
17	3, 3′-Dimethylnaphthidine (DMN)	
18	Diphenyl carbazone	*See* Table 27, No. 8 (p. 217)
19	Dithizone	*See* Table 49, No. 43 (p. 376)
20	Eriochrome Black T: *See* Acid Chrome Black Special, No. 1	
21	Eriochrome Blue-Black B	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
1% solution in glacial acetic acid	Zn^{2+}	pH 5; in the presence of $Fe(CN)_6^{3-}$	Violet—colourless
	Al^{3+}, Cd^{2+}, Cu^{2+}, Ni^{2+}, Pd^{2+}	pH 5; back titration in the presence of $Fe(CN)_6^{3-}$	
0.2% alcohol solution	Hg^{2+}	pH 1; HCl-KCl	Blue-violet—colourless
	Pb^{2+}	pH 4.5-6.5; acetic-acetate buffer	Red—colourless
0.075% solution in ethyl alcohol	Cd^{2+}	pH 4.5; 50% alcohol	Pink—yellow
	Zn^{2+}	pH 4-6; 50% alcohol or dimethyl ketone	Pink—blue, green or yellow, depending on pH
	Ni^{2+}	pH 4.5; 60% alcohol	Pink—yellow
	Pb^{2+}	pH 4.7-5.4; 50% alcohol in the presence of urotropine buffer	Pink—yellow
	Al^{3+}	pH 4-5; 50% alcohol; back titration with a zinc salt solution	
(p. 220)			
0.4% solution in methanol	Ca^{2+}, Cd^{2+}	pH 11.5; NH_3	Red—blue
	Mg^{2+}, Zn^{2+}	pH 10; ammonia buffer	Red—blue
	U^{IV}	0.01-0.2*M* HCl, hot solution	Blue—red
	Zr^{IV}	0.01-0.5*M* HCl; 50% methanol, hot solution	Blue—red

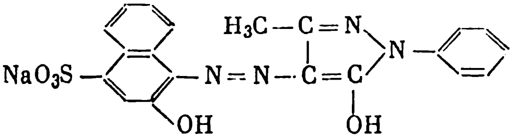
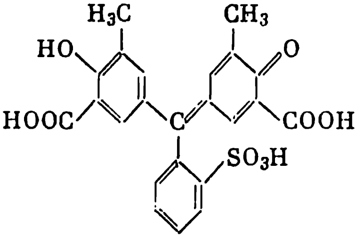
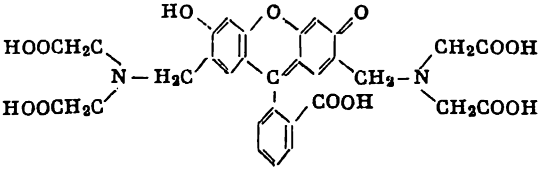
No.	Indicator	Formula
22	Eriochrome Red B	
23	Eriochrome Cyanine R	
24	Fluorexone (calcein, fluorescein complexone)	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
—	Ca^{2+}	pH 10; ammonia buffer	Red—yellow
	Cu^{2+}	pH 2; chloroacetic acid	Purple—yellow
		pH 4; acetato buffer	Purple—green
	Mn^{2+}	pH 8-10; ammonia buffer; ascorbic acid	Red—yellow
	Ni^{2+}	pH 4-6; acetate buffer	Purple—pale yellow
	Pb^{2+}	pH 10; ammonia buffer; tartrate	Orange red—yellow
	Zn^{2+}	pH 6.5; urotropine buffer	Red—yellow
0.4% aqueous solution	Al^{3+}	pH 5-6.3; acetate buffer, back titration with a zinc salt solution, 70-80 °C	Yellow—violet
	Zr^{IV}	pH 1.4; hot solution	Pink—colourless
	Fe^{3+}	pH 2-3; cloroacetic acid-acetate, 60 °C	Violet—yellow or green
	Th^{IV}	pH 2-2.5	Purple—pink
2% aqueous solution or solid mixture with KNO_3 in the ratio of 1 : 100	Ca^{2+}	$pH > 12$; KOH or NaOH	Fluorescence—blue or green
	Ba^{2+}, Sr^{2+}	pH 11.5; NH_3 or pH 12.5; KOH	Fluorescence—pink, almost colourless
	Cu^{2+}	pH 10-11; ammonia buffer	
	Mn^{2+}	pH 8-11; ammonia buffer $+ NH_2OH$	

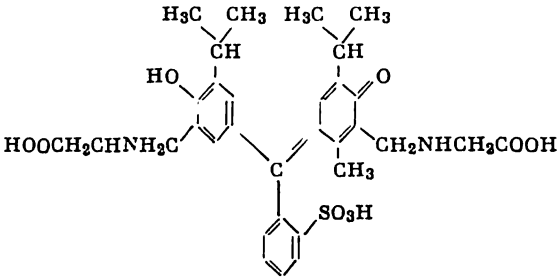
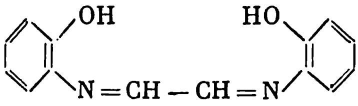
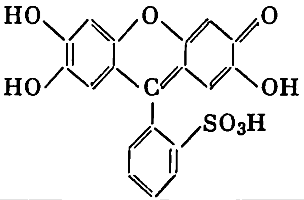
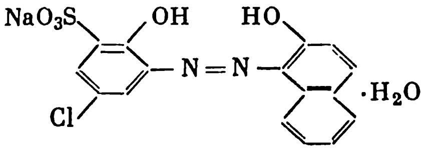
No.	Indicator	Formula
25	Glycinthymol blue (GTB)	
26	Glyoxal-bis-(2-hydroxyanil) (GBHA)	
27	Hematoxylin	*See* Table 19, No. 34 (p. 186)
28	Hydroxyhydroquinone pink (hydroxyhydroquinone sulphophthalein)	
29	Magneson	

Table 28 (continued)

	Concentration	Ions being determined	Conditions of determination	Change in colour
	0.1% aqueous solution	Cu^{2+}	pH 5-6; urotropine buffer	Blue—yellow
		Zn^{2+}	pH 7.5; pyridine buffer	
	—	Ca^{2+}	pH 13 (in the presence of KCN, the end point is more distinct)	Pink—yellow
	0.5% solution in 90% alcohol	Al^{3+}	pH 6; back titration with an aluminium salt solution	Yellow-green—pink
		Bi^{3+}	pH 1-2; HNO_3	Pink—pale yellow
		Th^{IV}	pH 2	Orange—yellow
		Zr^{IV}	pH 1-1.5	Pink—yellow
	0.1% aqueous solution	Th^{IV}, Bi^{3+}	pH 2.4-3; acetate buffer	Pink—yellow
	0.01% solution in water or acetone	Mg^{2+}	pH 9.8-11.2	Red—blue
		Ca^{2+}, Cd^{2+}	pH 11.5; NH_3	
		Ba^{2+}, Sr^{2+}	pH 12.5; $(C_2H_5)_2NH$ acetate buffer	
		Ni^{2+}	pH 4; hot solution	Red—orange

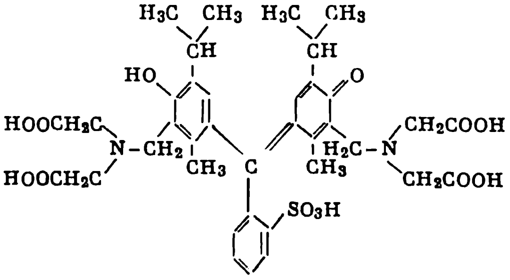
No.	Indicator	Formula
30	Metallphthalein: *See* Phthalein complexone, No. 39 (p. 242)	
31	Methylthymol blue (MTB)	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
Solid mixture of the indicator with KNO_3 in the ratio of 1 : 100	Ba^{2+}, Sr^{2+}	pH 10-11; ammonia buffer	Blue—gray
	Ca^{2+}	pH 12; NH_3 or NaOH	
	Mg^{2+}	pH 10-11.5; ammonia buffer	
	Bi^{3+}	pH 1-3; HNO_3	Blue—yellow
	Cd^{2+}, Co^{2+}	pH 5-6; urotropine buffer	
		pH 12; NH_3	Blue—gray or colourless
	Cu^{2+}	pH 11.5; NH_3	Blue—colourless or gray-green
	Fe^{2+}	pH 4.5-6.5; urotropine buffer	Blue—yellow
	Hg^{2+}	pH 6; urotropine buffer	
	In^{3+}	pH 3-4; acetate buffer	
	Mn^{2+}	pH 6-6.5; urotropine buffer	Blue—yellow
		pH 11.5; NH_3	Blue—gray
	Pb^{2+}	pH 6; urotropine buffer	Blue—yellow
		pH 12; NH_3 in the presence of tartrate	Blue—gray
	RE	pH 6; urotropine buffer	Blue—yellow
		pH 2.2; HNO_3	
	Sn^{2+}	pH 5.5-6; pyridine + + acetate + F^-	Blue—yellow
	Zn^{2+}	pH 6-6.5; urotropine buffer	Blue—yellow
		pH 12; NH_3	Blue—gray
	Zr^{IV}	pH 1-2; chloroacetic acid, 90 °C	Blue—red
	Ga^{3+}, In^{3+}	pH 4.5-6; acetate buffer	Disappearance of fluorescence

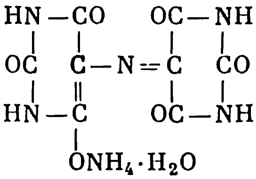
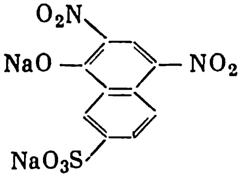
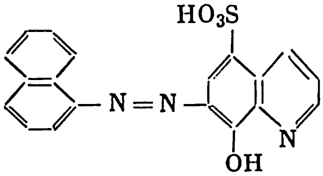
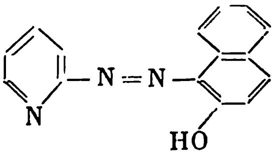
No.	Indicator	Formula
32	Morin: *See* Table 25, No. 25 (p. 211)	
33	Murexide	
34	Naphthol yellow	
35	Naphthylazoxine	
36	PAN[1-(2-pyridylazo)-naphthol-2]	

Table 28 (continued)

	Concentration	Ions being determined	Conditions of determination	Change in colour
		Ga^{3+}, In^{3+}	pH 4.5-6; acetate buffer	Disappearance of fluorescence
	Mixture of the indicator (0.2 wt. %) and solid sodium chloride	Ca^{2+}	pH $\geqslant$ 12	Red—violet
		Co^{2+}	pH 8; NH_3	Orange—violet
		Cu^{2+}	pH 7-8; NH_3	
		Ni^{2+}	pH 8.5-9.5; NH_3	
		Ag^{+}	pH 10-11.5; NH_3	Red—violet
		Pd^{2+}	Addition of $K_2Ni(CN)_4+$ $+NH_4OH$	Yellow—violet
	Used in mixture with Acid Chrome Dark Green G (No. 3)			
	—	Cu^{2+}	pH 3.5-6.5; acetate buffer pH 9.3; ammonia buffer	Yellow—red Yellow-green—pink
		Mn^{2+}	pH 6.7-7.0; acetate buffer	Yellow—red
		Ni^{2+}	pH 5.5-6.5; acetate or pyridine buffer	
		Pb^{2+}	pH 6-6.5; acetate or pyridine buffer	
	0.1% solution in ethanol or methanol	Bi^{3+}	pH 1-3; HNO_3	Red—yellow-green

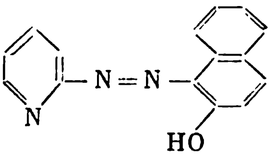
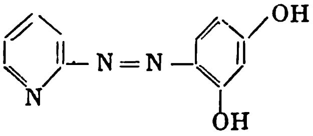
No.	Indicator	Formula
36	PAN [1-(2-pyridylazo)-naphthol-2]	
37	PAR [4-(2-pyridylazo)-resorcinol]	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
0.1% solution in ethanol or methanol	Cd^{2+}	pH 5-6; acetate buffer	Pink—yellow-green
	Cu^{2+}	pH 3-5; acetate buffer, 70-80 °C	
		pH 9-10; ammonia buffer, 50 °C	Violet—yellow
	In^{3+}	pH 2.3-2.5; acetate buffer, hot solution	Red—yellow
	Ni^{2+}	pH 4; 25% methanol, 50-70 °C	Violet-red—yellow
	Th^{IV}	pH 2-3.5; HNO_3	Red—yellow
	Tl^{3+}	pH > 1.8; chloroacetic acid, hot solution	
	Zn^{2+}	pH 4-6; acetate buffer	
	Al^{3+}, Ca^{2+}, Co^{2+}, Fe^{3+}, Hg^{2+}, Ga^{3+}, Mg^{2+}, Mn^{2+}, Mo^{V}, Ni^{2+}, Pb^{2+}, RE, UO_2^{2+}, VO^{2+}	Back titration with a cupric salt solution	
0.1% aqueous solution	Bi^{3+}	pH 1-2; HNO_3	Red—yellow
	Tl^{3+}	pH 1.7; hot solution	
	In^{3+}	pH 2.3-2.5; 60-70 °C	
	Hg^{2+}	pH 3-6	Red—yellow-orange
	Cd^{2+}	pH 6-11.5; ammonia or urotropine buffer	Red—yellow
	Cu^{2+}	pH 5; acetate buffer pH 6; urotropine buffer pH 11.5; ammonia buffer	Wine red—yellow or green

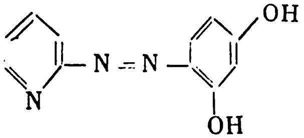
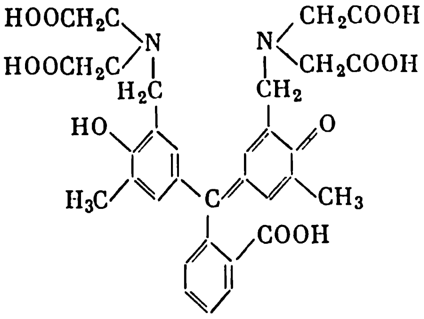
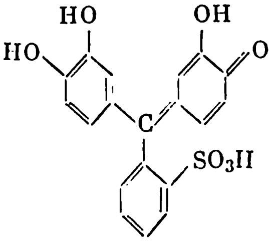
No.	Indicator	Formula
37	PAR [4-(2-pyridyl-azo)-resorcinol]	
38	Patton-Reeder Dye: *See* Calces, No. 10 (p. 226)	
39	Phthalein complexone (metallphthalein; phthalein purple; cresolphthalexone)	
40	Pyrocatechin violet (pyrocatechin sulphophthalein)	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
0.1% aqueous solution	Mn^{2+}	pH 9; ammonia buffer	Red—yellow
	Ni^{2+}	pH 5; acetate buffer, 90 °C	Red—yellow
	Pb^{2+}	pH 5-9.6; urotropine or ammonia buffer	Red—yellow
	RE and Y^{3+}	pH 6; acetate buffer	Red—yellow
	Zn^{2+}	pH 5-11.5; urotropine or ammonia buffer	Red—yellow
(a) 0.5% aqueous solution	Ba^{2+}, Sr^{2+}	pH 10.5-11; addition of ethanol	(a) Red-violet—pale pink or colourless
(b) mixture of 0.1 g of phthalein complexone, 0.005 g of methyl red and 0.005 g of diamine green in 100 ml of water	Mg^{2+}	pH 10-11; NH_3; addition of ethanol	(b) Red—pale gray
	Ca^{2+}	pH 10-11	
	Cd^{2+}	pH 10; ammonia buffer + 30% of ethanol	
0.1% aqueous solution	Bi^{3+}	pH 2-3; HNO_3	Blue—yellow
	Cd^{2+}	pH 10; ammonia buffer	Greenish blue—red-violet
	Co^{2+}	pH 9.3; ammonia buffer	
	Ni^{2+}	pH 8-9.3; ammonia buffer	
	Cu^{2+}	pH 5-6.5; acetate buffer	Blue—yellow
		pH 6-7; pyridine buffer	
		pH 9.3; ammonia buffer	Blue—red-violet

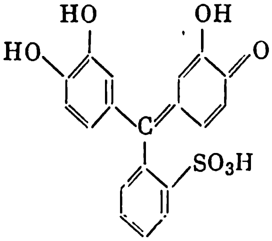
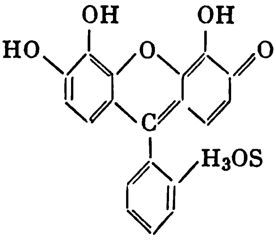
No.	Indicator	Formula
40	Pyrocatechin violet (pyrocatechin sulphophthalein)	
41	Pyrogallol red	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
0.1% aqueous solution	Fe^{3+}	pH 5-6; pyridine-acetate buffer	Blue—yellow-green
	Ga^{3+}	pH 3-3.8; acetate buffer	Blue—yellow
	In^{3+}	pH 5; acetate buffer, hot solution	Blue—yellow
	Mg^{2+}, Zn^{2+}	pH 10; ammonia buffer	Greenish blue—red-violet
	Mn^{2+}	pH 9.3; ammonia buffer + NH_2OH	
	Th^{IV}	pH 2.5-3.5; HNO_3, 40 °C	Red—yellow
	Pb^{2+}	pH 5.5; urotropine buffer	Blue—yellow
	Al^{3+}, Fe^{3+}, Ga^{3+}, In^{3+}, Pd^{2+}, Th^{IV}, Tl^{3+}	Back titration with a cupric or bismuth salt solution	
	Sn^{IV}	pH 5; back titration with a zinc salt solution, 70-80 °C	
0.05% solution in 50% ethanol	Bi^{3+}	pH 2-3; HNO_3	Red—orange-yellow
	Co^{2+}, Ni^{2+}	pH 9.3; ammonia buffer	Blue—wine red
	Pb^{2+}	pH 5-6; acetate buffer	Violet—red
	Cu^{2+}, Fe^{3+}, Ga^{3+}, In^{3+}, Pd^{2+}, Th^{IV}	Back titration with a lead salt or a bismuth salt solution	

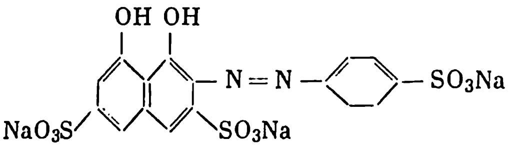
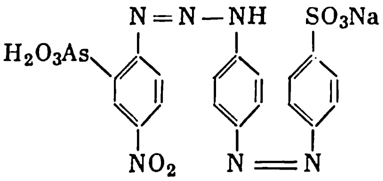
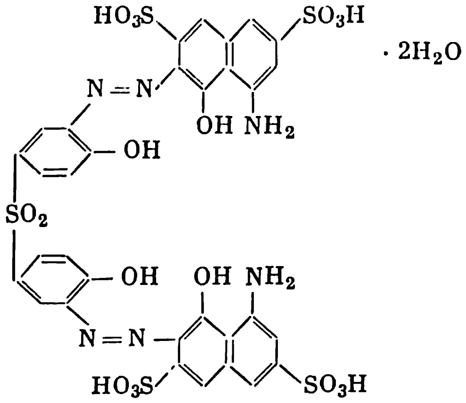
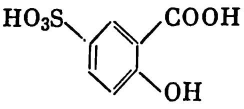
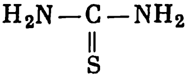
No.	Indicator	Formula
42	SPADNS	
43	Sulpharsasene (plumbone)	
44	Sulphonazo	
45	Sulphosalicylic acid	
46	Thiourea	 $H_2N-\underset{\underset{S}{\|}}{C}-NH_2$

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
0.4% aqueous solution	Zr^{IV}	pH 1.5-2.5; HNO_3	Red-pink—orange-red
0.02% aqueous solution	Th^{IV}	pH 2.5-3.5; HNO_3	Violet-blue—purple-red
0.05% aqueous solution with an addition of 1-2 drops of 5% ammonia solution	Pb^{2+}	pH 9.8-10 in the presence of tartaric acid and ammonia	Orange-pink—lemon yellow
	Zn^{2+}	pH 9.3-9.6 in the presence of tartaric acid and ammonia	ditto
0.02% aqueous solution	Sc^{3+}	pH 5	Blue—violet-pink
	In^{3+}		Blue-violet—violet-pink
5% aqueous solution	Fe^{3+}	pH 2-3; acetate buffer, hot solution	Red—yellow
Aqueous solution	Bi^{3+}	pH 1.5-2.0; HNO_3 or $HClO_4$	Yellow—colourless

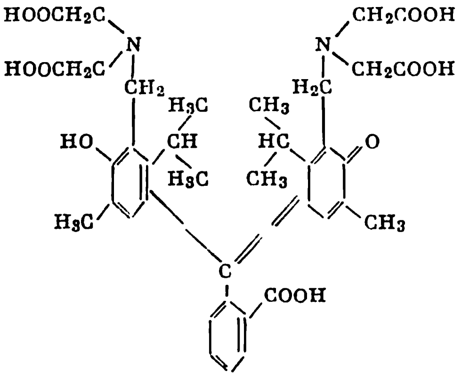
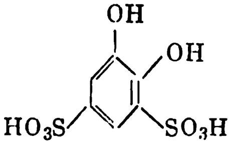
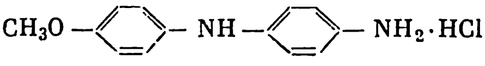
No.	Indicator	Formula
47	Thoron (thorin, APANS)	*See* Table 49, No. 93 (p. 396)
48	Thymolphthalexone	 HOOCH₂C N HOOCH₂C CH₂ H₃C CH H₃C HO H₃C CH₂COOH N CH₂COOH H₂C CH₃ HC CH₃ O CH₃ C COOH
49	Thyron	
50	Variamine Blue B	

Table 28 (continued)

	Concentration	Ions being determined	Conditions of determination	Change in colour
	Aqueous solution	Bi^{3+}	pH 2-3; HNO_3	Red—yellow
		Th^{IV}	pH 1-3; HNO_3	Violet—yellow
		U^{IV}	pH 1-1.8; 30 °C	Red-orange—orange-yellow
	0.5% aqueous solution or solid mixture with KNO_3 in the ratio of 1 : 100	Ba^{2+}, Sr^{2+}	pH 10-11; NaOH or NH_3	Blue—gray or colourless
		Ca^{2+}	pH 10.5-12; NaOH or NH_3	
		Mn^{2+}	pH 10-11; NH_3, NaOH	Blue—colourless
	2% aqueous solution	Fe^{3+}	pH 2-3; acetate buffer, hot solution	Blue—colourless
	1% aqueous solution	Fe^{3+}	pH 1.7-3	Blue violet—yellow
		Cd^{2+}, Zn^{2+}	pH 5; in the presence of traces of $Fe(CN)_6^{4-}$ and $Fe(CN)_6^{3-}$	Violet—colourless
		Al^{3+}, Pb^{2+}, Zr^{IV}	Back titration with a zinc salt solution	

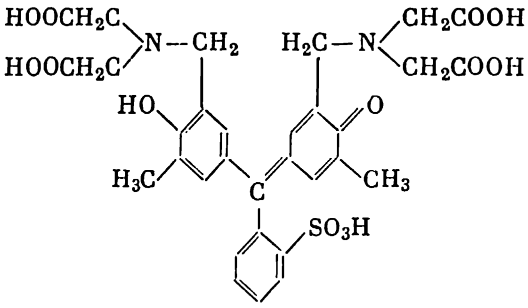
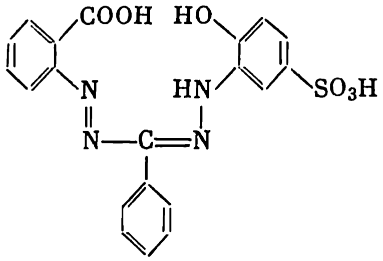
No.	Indicator	Formula
51	Xylenol orange	
52	Zincon	

Table 28 (continued)

Concentration	Ions being determined	Conditions of determination	Change in colour
0.5% solution in ethanol	Bi^{3+}	pH 1-3; HNO_3	Red—yellow
	Th^{IV}	pH 1.7-3.5; HNO_3	
	Zr^{IV}	HNO_3; 1*M*, 90 °C	
	Sc^{3+}	pH 2.2-5	
	In^{3+}	pH 3-3.5; acetate buffer, hot solution	
	Hg^{2+}, Tl^{3+}	pH 4-5; acetate buffer	
	Cd^{2+}, Fe^{2+}	pH 5-6; urotropine buffer	
	Co^{2+}	pH 5-6; urotropine buffer, 80 °C	Red-violet—yellow
	RE^{3+}	pH 5-6; urotropine buffer, hot solution	Red—yellow
	Pb^{2+}	pH 5; acetate buffer or pH 6; urotropine buffer	
	Zn^{2+}	pH 5-6; acetate buffer; pH 7; urotropine buffer	
	Fe^{3+}	pH 1.5; in the presence of Fe^{2+}, CO_2 atmosphere, 60 °C	Blue-violet—yellow
	Al^{3+}, Fe^{3+}, Ga^{3+}, Ni^{2+}, Pd^{2+}, Sn^{IV}, U^{IV}, VO^{2+}	Back titration with a thorium (IV) salt solution	
0.130 g of the indicator and 2 ml of 1*M* NaOH solution in 100 ml of water	Ca^{2+}, Ge^{IV}, Co^{2+}, Cu^{2+}, Fe^{3+}, In^{3+}, Mn^{2+}, Pb^{2+}	pH 9-10; back titration with a zinc salt solution	
	Zn^{2+}	pH 9-10; ammonia buffer	Blue—yellow

Table 29

Hydrogen Ion Exponent (pH) Evaluated in Terms of the Activity of Hydrogen Ions (a_{H^+}) and Vice Versa (pH = — log a_{H^+})

The table can be used to convert the indices of the solubility product pSP into the solubility product SP, the indices of constants p*K* into constants *K*, and in other similar cases.

Decimal fractions of pH	Centesimal fractions of pH									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	values of a_{H^+}									
.0	1.000	0.977	0.955	0.933	0.912	0.891	0.871	0.851	0.832	0.813
.1	0.794	0.766	0.759	0.741	0.725	0.708	0.692	0.676	0.661	0.646
.2	0.631	0.617	0.603	0.589	0.575	0.562	0.550	0.537	0.525	0.513
.3	0.501	0.490	0.479	0.468	0.457	0.447	0.437	0.427	0.417	0.407
.4	0.398	0.389	0.380	0.372	0.363	0.355	0.347	0.339	0.331	0.324
.5	0.316	0.309	0.302	0.295	0.288	0.282	0.275	0.269	0.263	0.257
.6	0.251	0.245	0.240	0.234	0.229	0.224	0.219	0.214	0.209	0.204
.7	0.200	0.195	0.191	0.186	0.182	0.178	0.174	0.170	0.166	0.162
.8	0.158	0.155	0.151	0.148	0.145	0.141	0.138	0.135	0.132	0.129
.9	0.126	0.123	0.120	0.117	0.115	0.112	0.110	0.107	0.105	0.102

To calculate a_{H^+} by a known pH, the first digit of the mantissa of the pH value is found in the first vertical column, and the second digit of this mantissa is found in the first horizontal line. The value of a_{H^+} is obtained at the intersection of the lines which start from the figures found. This value must be multiplied by 10 to the power equal to the characteristic of the pH taken with a negative sign. For example: pH = 6.27; $a_{H^+} = 0.537 \times 10^{-6}$.

To calculate the pH by a known value of a_{H^+}, the latter should be expressed by a number which starts with 0 and is multiplied by 10 to a certain negative power. Then, this number (or one close to it) is found in the table and, proceeding from it to the left and upward, two digits are obtained after the decimal in the pH value. The characteristic of the pH will be equal to the power to which 10 is raised in the number of a_{H^+}, but with a positive sign. For example, $a_{H^+} = 2.41 \times 10^{-7} = 0.241 \times 10^{-6}$; pH = 6.62.

Table 30

Preparation of Buffer Solutions

(pH ranging from 1.10 to 12.90; $t = 20\,^\circ C$)

Stock solutions

Solution No. 1: hydrochloric acid, 0.1*N*.

Solution No. 2: glycocoll NH_2CH_2COOH (aminoacetic acid, glycin), 0.1*N* (7.507 g of glycocoll + 5.85 g of NaCl in one litre).

Solution No. 3: potassium hydrophthalate, $KHC_8H_4O_4$ 0.2*M* (40.846 g in one litre).

Solution No. 4: sodium citrate, 0.1*M* (21.014 g of $H_3C_6H_5O_7 \cdot H_2O +$ + 200 ml of 1*N* NaOH solution in one litre).

Solution No. 5: caustic soda, 0.1*N*.

Solution No. 6: potassium dehydrophosphate, 1/15*M* (9.073 g of KH_2PO_4 in one litre).

Solution No. 7: sodium hydrophosphate, 1/15*M* (11.866 g of $Na_2HPO_4 \cdot 2H_2O$ in one litre).

Solution No. 8: sodium tetraborate, 0.05*M* (12.367 g of $H_3BO_3 +$ + 100 ml of 1*N* NaOH solution in one litre).

Chemically pure sodium chloride is recrystallized twice and dried at a temperature of 120 °C; chemically pure boric acid is recrystallized twice out of boiling water and dried at a temperature of not over 80 °C; chemically pure potassium dehydrophosphate is recrystallized twice and dried at a temperature of 110-120 °C; chemically pure sodium hydrophosphate is recrystallized twice (during the last crystallization, the temperature of the solution must not be over 90 °C), then damped with water and dried for two days in a thermostat at a temperature of 36 °C; chemically pure citric acid is recrystallized twice (during the last crystallization, the temperature must not be higher than 60 °C); potassium hydrophthalate is recrystallized twice and dried at a temperature of 110-120 °C.

A. Buffer Solutions with pH 1.10-3.50 (HCl-NH_2CH_2COOH)

Every given amount of the solution (solution No. 2, see above) is brought up to 100 ml with solution No. 1 (see above)

pH	0	1	2	3	4	5	6	7	8	9
1.1	5.7	6.6	7.5	8.4	9.3	10.2	11.1	12.0	12.8	13.7
2	14.6	15.4	16.2	17.0	17.8	18.6	19.4	20.2	21.0	21.8
3	22.6	23.2	23.9	24.5	25.2	25.8	26.4	27.0	27.7	28.3
4	28.9	29.4	30.0	30.5	31.1	31.6	32.0	32.5	32.9	33.4
5	33.8	34.2	34.6	35.0	35.4	35.8	36.2	36.7	37.1	37.6
6	38.0	38.4	38.7	39.1	39.4	39.8	40.2	40.6	40.9	41.3
7	41.7	42.1	42.4	42.8	43.1	43.5	43.9	44.2	44.6	44.9

Table 30 (*continued*)

pH	0	1	2	3	4	5	6	7	8	9
8	45.3	45.6	46.0	46.3	46.7	47.0	47.4	47.8	48.1	48.5
9	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0	51.3	51.6
2.0	51.9	52.2	52.5	52.8	53.1	53.4	53.7	54.0	54.3	54.6
1	54.9	55.2	55.4	55.7	55.9	56.2	56.5	56.7	57.0	57.3
2	57.6	57.9	58.2	58.4	58.7	59.0	59.3	59.5	59.8	60.0
3	60.3	60.6	61.0	61.3	61.7	62.0	62.3	62.6	63.0	63.3
4	63.6	63.9	64.2	64.5	64.8	65.1	65.4	65.7	66.0	66.3
5	66.6	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0	69.3
6	69.6	69.9	70.2	70.5	70.8	71.1	71.4	71.8	72.1	72.5
7	72.8	73.1	73.4	73.8	74.1	74.4	74.7	75.0	75.4	75.7
8	76.0	76.3	76.6	77.0	77.3	77.6	77.9	78.2	78.6	78.9
9	79.2	79.5	79.8	80.1	80.4	80.7	81.0	81.3	81.5	81.8
3.0	82.1	82.4	82.7	82.9	83.2	83.5	83.8	84.0	84.3	84.5
1	84.8	85.0	85.3	85.5	85.8	86.0	86.2	86.4	86.7	86.9
2	87.1	87.3	87.5	87.8	88.0	88.2	88.4	88.6	88.8	89.0
3	89.2	89.4	89.6	89.7	89.9	90.1	90.3	90.5	90.6	90.8
4	91.0	91.2	91.3	91.5	91.6	91.8	91.9	92.1	92.2	92.4
5	92.5									

B. Buffer Solutions with pH 1.10-4.96 (HCl-$NaH_2C_6H_5O_7$)

Every given amount of the solution (solution No. 4, see p. 253) is brought up to 100 ml with solution No. 1 (*ibid*)

pH	0	1	2	3	4	5	6	7	8	9
1.1	4.8	5.6	6.4	7.1	7.8	8.4	9.0	9.6	10.1	10.6
2	11.1	11.6	12.1	12.5	13.0	13.5	14.0	14.5	14.9	15.4
3	15.9	16.2	16.6	16.9	17.3	17.6	17.9	18.3	18.6	19.0
4	19.3	19.6	19.9	20.2	20.5	20.8	21.1	21.4	21.6	21.9
5	22.2	22.4	22.7	22.9	23.2	23.4	23.6	23.9	24.1	24.4
6	24.6	24.8	25.0	25.2	25.4	25.6	25.8	26.0	26.1	26.3
7	26.5	26.7	26.9	27.0	27.2	27.4	27.6	27.7	27.9	28.0
8	28.2	28.3	28.5	28.6	28.8	28.9	29.0	29.1	29.3	29.4
9	29.5	29.6	29.7	29.9	30.0	30.1	30.2	30.3	30.4	30.5
2.0	30.6	30.7	30.8	31.0	31.1	31.2	31.3	31.4	31.5	31.6
1	31.7	31.8	31.9	31.9	32.0	32.1	32.2	32.3	32.4	32.5
2	32.6	32.7	32.8	32.9	33.0	33.1	33.2	33.3	33.4	33.5
3	33.6	33.7	33.8	33.8	33.9	34.0	34.1	34.2	34.3	34.4
4	34.5	34.6	34.7	34.8	34.9	35.0	35.1	35.2	35.2	35.3

Table 30 (continued)

pH	0	1	2	3	4	5	6	7	8	9
5	35.4	35.5	35.6	35.7	35.8	35.9	36.0	36.1	36.2	36.3
6	36.4	36.5	36.6	36.7	36.8	36.9	37.0	37.1	37.1	37.2
7	37.3	37.4	37.5	37.6	37.7	37.8	37.9	38.0	38.1	38.2
8	38.3	38.4	38.5	38.6	38.7	38.8	38.9	39.0	39.1	39.2
9	39.3	39.4	39.5	39.6	39.7	39.8	39.9	40.0	40.1	40.2
3.0	40.3	40.4	40.5	40.7	40.8	40.9	41.0	41.1	41.3	41.4
1	41.5	41.6	41.7	41.8	41.9	42.0	42.1	42.3	42.4	42.6
2	42.7	42.8	42.9	43.1	43.2	43.3	43.4	43.6	43.7	43.9
3	44.0	44.1	44.3	44.4	44.6	44.7	44.8	45.0	45.1	45.3
4	45.4	45.5	45.7	45.8	46.0	46.1	46.2	46.4	46.5	46.7
5	46.8	47.0	47.1	47.3	47.4	47.6	47.8	47.9	48.1	48.2
6	48.4	48.6	48.8	48.9	49.1	49.3	49.5	49.6	49.8	49.9
7	50.1	50.3	50.5	50.6	50.8	51.0	51.2	51.4	51.5	51.7
8	51.9	52.1	52.3	52.5	52.7	52.9	53.1	53.3	53.4	53.6
9	53.8	54.0	54.2	54.5	54.7	54.9	55.1	55.3	55.6	55.8
4.0	56.0	56.3	56.5	56.8	57.0	57.3	57.5	57.8	58.0	58.3
1	58.5	58.7	59.0	59.2	59.5	59.7	60.0	60.3	60.5	60.8
2	61.1	61.4	61.7	62.0	62.3	62.6	62.9	63.3	63.6	64.0
3	64.3	64.7	65.1	65.4	65.7	66.0	66.4	66.8	67.1	67.5
4	67.9	68.3	68.7	69.0	69.4	69.8	70.2	70.6	71.1	71.5
5	71.9	72.4	72.9	73.4	73.9	74.4	74.9	75.4	75.9	76.4
6	76.9	77.4	78.0	78.5	79.1	79.6	80.1	80.6	81.2	81.7
7	82.2	82.8	83.3	83.9	84.4	85.0	85.6	86.2	86.6	87.4
8	88.0	88.7	89.4	90.0	90.7	91.4	92.2	93.1	93.9	94.8
9	95.6	96.3	97.1	97.8	98.5	99.3	100.0			

C. Buffer Solutions with pH 2.20-3.80 ($HCl-KHC_8H_4O_4$)

50.0 ml of solution No. 3 (see p. 253) is added to every given amount of the solution (solution No. 1, *ibid*), and the amount of the mixture is brought up to 200 ml with water

pH	0	1	2	3	4	5	6	7	8	9
2.2	93.20	92.50	91.80	91.10	90.40	89.70	89.00	88.30	87.60	86.90
3	86.20	85.50	84.80	84.10	83.40	82.70	82.00	81.30	80.60	79.90
4	79.20	78.54	77.88	77.22	76.56	75.90	75.24	74.58	73.92	73.26
5	72.60	71.94	71.28	70.62	69.96	69.30	68.64	67.98	67.32	66.66
6	66.00	65.34	64.68	64.02	63.36	62.70	62.04	61.38	60.72	60.06
7	59.40	58.76	58.12	57.48	56.84	56.20	55.56	54.92	54.28	53.64

Table 30 (continued)

pH	0	1	2	3	4	5	6	7	8	9
8	53.00	52.38	51.76	51.14	50.52	49.90	49.28	48.66	48.04	47.42
9	46.80	46.20	45.60	45.00	44.40	43.80	43.20	42.60	42.00	41.40
3.0	40.80	40.22	39.64	39.06	38.48	37.90	37.32	36.74	36.16	35.58
1	35.00	34.44	33.88	33.32	32.78	32.24	31.70	31.16	30.64	30.12
2	29.60	29.08	28.56	28.04	27.54	27.04	26.54	26.04	25.56	25.08
3	24.60	24.12	23.64	23.16	22.68	22.20	21.72	21.26	20.80	20.34
4	19.90	19.46	19.02	18.58	18.16	17.74	17.32	16.90	16.50	16.10
5	15.70	15.30	14.90	14.52	14.16	13.80	13.44	13.08	12.72	12.36
6	12.00	11.66	11.32	10.98	10.64	10.30	9.96	9.62	9.28	8.94
7	8.60	8.26	7.92	7.58	7.24	6.90	6.58	6.26	5.94	5.62
8	5.30									

D. Buffer Solutions with pH 4.00-6.20 (NaOH-$KHC_8H_4O_4$)

50.0 ml of solution No. 3 (see p. 253) is added to every given amount of the solution (solution No. 5, *ibid*), and the amount of the mixture is brought up to 200 ml with water

pH	0	1	2	3	4	5	6	7	8	9
4.0	0.80	1.14	1.46	1.80	2.12	2.46	2.78	3.12	3.44	3.78
1	4.10	4.44	4.76	5.10	5.42	5.76	6.08	6.42	6.74	7.08
2	7.40	7.74	8.08	8.42	8.78	9.14	9.50	9.86	10.24	10.62
3	11.00	11.38	11.76	12.14	12.54	12.94	13.34	13.74	14.16	14.58
4	15.00	15.42	15.84	16.26	16.68	17.10	17.54	17.98	18.42	18.86
5	19.30	19.76	20.24	20.72	21.22	21.72	22.22	22.74	23.26	23.78
6	24.30	24.84	25.38	25.92	26.46	27.00	27.54	28.08	28.62	29.16
7	29.70	30.26	30.82	31.38	31.94	32.50	33.08	33.66	34.24	34.82
8	35.40	35.98	36.56	37.14	37.74	38.34	38.94	39.54	40.16	40.78
9	41.40	42.04	42.68	43.32	43.96	44.60	45.22	45.84	46.46	47.08
5.0	47.70	48.32	48.94	49.56	50.18	50.80	51.42	52.04	52.66	53.28
1	53.90	54.50	55.10	55.70	56.30	56.90	57.50	58.10	58.70	59.30
2	59.90	60.50	61.10	61.70	62.28	62.86	63.44	64.02	64.58	65.14
3	65.70	66.24	66.78	67.32	67.84	68.36	68.88	69.40	69.90	70.40
4	70.90	71.38	71.86	72.34	72.82	73.30	73.76	74.22	74.68	75.14
5	75.60	76.04	76.46	76.88	77.30	77.72	78.12	78.52	78.92	79.32
6	79.70	80.08	80.44	80.80	81.14	81.48	81.82	82.14	82.46	82.78
7	83.10	83.40	83.70	84.00	84.30	84.60	84.88	85.16	85.44	85.72
8	86.00	86.28	86.56	86.84	87.10	87.36	87.62	87.88	88.12	88.36
9	88.60	88.84	89.08	89.32	89.56	89.80	90.02	90.24	90.46	90.68
6.0	90.90	91.10	91.30	91.50	91.70	91.90	92.08	92.26	92.44	92.62
1	92.80	92.96	93.10	93.24	93.36	93.48	93.60	93.70	93.80	93.90
2	94.00									

Table 80 (continued)

E. Buffer Solutions with pH 4.96-6.69 ($NaOH$-$NaH_2C_6H_5O_7$)

Every given amount of the solution (solution No. 5, p. 253) is brought up to 100 ml with solution No. 4 (*ibid*)

pH	0	1	2	3	4	5	6	7	8	9
4.9	—	—	—	—	—	—	0.0	0.9	1.8	2.7
5.0	3.6	4.3	5.0	5.6	6.3	7.0	7.5	8.1	8.6	9.2
1	9.7	10.2	10.8	11.3	11.9	12.4	12.9	13.4	13.9	14.4
2	14.9	15.4	15.9	16.5	17.0	17.5	17.9	18.3	18.8	19.2
3	19.6	20.0	20.4	20.8	21.2	21.6	22.0	22.4	22.9	23.3
4	23.7	24.1	24.5	24.9	25.3	25.7	26.1	26.5	26.9	27.3
5	27.7	28.0	28.4	28.7	29.1	29.4	29.7	30.0	30.4	30.7
6	31.0	31.3	31.6	31.9	32.2	32.5	32.8	33.1	33.4	33.7
7	34.0	34.3	34.5	34.8	35.0	35.3	35.5	35.8	36.0	36.2
8	36.4	36.6	36.8	37.1	37.3	37.5	37.7	37.9	38.1	38.3
9	38.5	38.7	38.9	39.1	39.3	39.5	39.7	39.9	40.0	40.2
6.0	40.4	40.6	40.8	41.0	41.2	41.4	41.5	41.6	41.7	41.9
1	42.0	42.1	42.3	42.4	42.6	42.7	42.8	43.0	43.1	43.3
2	43.4	43.5	43.6	43.8	44.0	44.1	44.2	44.3	44.4	44.5
3	44.6	44.7	44.8	44.9	45.0	45.1	45.2	45.3	45.3	45.4
4	45.5	45.6	45.7	45.7	45.8	45.9	46.0	46.1	46.1	46.2
5	46.3	46.4	46.5	46.5	46.6	46.7	46.8	46.8	46.9	46.9
6	47.0	47.1	47.1	47.2	47.2	47.3	47.3	47.4	47.4	47.5

F. Buffer Solutions with pH 4.80-8.00 (KH_2PO_4-Na_2HPO_4)

Every given amount of the solution (solution No. 7, p. 253) is brought up to 100 ml with solution No. 6 (*ibid*)

pH	0	1	2	3	4	5	6	7	8	9
4.8	0.35	0.37	0.39	0.41	0.43	0.45	0.48	0.51	0.54	0.57
9	0.60	0.63	0.66	0.69	0.72	0.75	0.79	0.83	0.87	0.91
5.0	0.95	0.99	1.03	1.07	1.11	1.15	1.19	1.23	1.27	1.31
1	1.35	1.39	1.43	1.47	1.51	1.55	1.60	1.65	1.70	1.75
2	1.80	1.85	1.90	1.95	2.00	2.05	2.10	2.15	2.20	2.25
3	2.30	2.37	2.44	2.51	2.58	2.65	2.72	2.79	2.86	2.93
4	3.00	3.09	3.18	3.27	3.36	3.45	3.54	3.63	3.72	3.81
5	3.90	3.99	4.08	4.17	4.26	4.35	4.46	4.57	4.68	4.79
6	4.90	5.02	5.14	5.26	5.38	5.50	5.62	5.75	5.90	6.05
7	6.20	6.35	6.50	6.70	6.85	7.00	7.20	7.35	7.55	7.70
8	7.90	8.10	8.25	8.45	8.60	8.80	9.00	9.20	9.40	9.60
9	9.80	10.0	10.2	10.4	10.6	10.8	11.1	11.3	11.6	11.8

Table 30 (continued)

pH	0	1	2	3	4	5	6	7	8	9
6.0	12.1	12.4	12.7	12.9	13.2	13.5	13.8	14.1	14.4	14.7
1	15.0	15.3	15.7	16.0	16.4	16.7	17.0	17.4	17.7	18.1
2	18.4	18.7	19.1	19.4	19.8	20.1	20.5	20.9	21.3	21.7
3	22.1	22.5	22.9	23.4	23.8	24.2	24.6	25.1	25.5	26.0
4	26.4	26.9	27.3	27.8	28.2	28.7	29.2	29.7	30.3	30.8
5	31.3	31.9	32.4	33.0	33.5	34.1	34.7	35.3	35.9	36.5
6	37.1	37.7	38.3	38.9	39.4	40.0	40.6	41.2	41.8	42.4
7	43.0	43.6	44.2	44.8	45.4	46.0	46.6	47.3	47.9	48.6
8	49.2	49.8	50.4	51.0	51.6	52.2	52.8	53.4	54.0	54.6
9	55.2	55.8	56.4	57.0	57.6	58.2	58.8	59.4	60.0	60.6
7.0	61.2	61.8	62.4	63.0	63.6	64.2	64.8	65.4	65.9	66.5
1	67.0	67.6	68.1	68.7	69.2	69.8	70.4	70.9	71.5	72.0
2	72.6	73.2	73.7	74.3	74.8	75.4	75.9	76.3	76.8	77.2
3	77.7	78.1	78.6	79.0	79.5	79.9	80.3	80.7	81.0	81.4
4	81.8	82.1	82.5	82.8	83.2	83.5	83.8	84.2	84.5	84.9
5	85.2	85.5	85.9	86.2	86.6	86.9	87.2	87.5	87.9	88.2
6	88.5	88.8	89.1	89.3	89.6	89.9	90.2	90.4	90.7	90.9
7	91.2	91.4	91.7	91.9	92.2	92.4	92.6	92.9	93.1	93.4
8	93.6	93.8	94.0	94.2	94.4	94.6	94.8	95.0	95.1	95.3
9	95.5	95.6	95.8	95.9	96.1	96.2	96.3	96.5	96.6	96.8
8.0	96.9									

G. Buffer Solutions with pH 7.71-9.23 ($Na_2B_4O_7$-HCl)

Every given amount of the solution (solution No. 8, p. 253) is brought up to 100 ml with solution No. 1 (*ibid*)

pH	0	1	2	3	4	5	6	7	8	9
7.7	—	52.5	52.6	52.7	52.8	52.9	53.0	53.1	53.2	53.3
8	53.4	53.5	53.6	53.7	53.85	53.95	54.1	54.25	54.4	54.55
9	54.65	54.75	54.85	55.0	55.1	55.25	55.35	55.5	55.6	55.75
8.0	55.85	56.0	56.1	56.25	56.35	56.5	56.6	56.75	56.9	57.0
1	57.15	57.25	57.4	57.5	57.65	57.8	57.95	58.1	58.3	58.45
2	58.65	58.8	59.0	59.2	59.4	59.6	59.8	60.0	60.2	60.45
3	60.7	60.95	61.15	61.4	61.6	61.85	62.05	62.3	62.5	62.7
4	62.95	63.2	63.45	63.65	63.9	64.1	64.35	64.55	64.8	65.0
5	65.25	65.5	65.75	66.05	66.3	66.6	66.9	67.2	67.5	67.75
6	68.0	68.25	68.55	68.8	69.1	69.4	69.7	70.0	70.4	70.8

Table 30 (continued)

pH	0	1	2	3	4	5	6	7	8	9
7	71.2	71.6	72.0	72.4	72.8	73.2	73.6	74.0	74.5	75.0
8	75.5	76.0	76.5	77.0	77.5	78.0	78.5	79.0	79.5	80.0
9	80.5	81.0	81.5	82.0	82.5	83.0	83.5	84.0	84.5	85.0
9.0	85.6	86.25	86.9	87.5	88.1	88.75	89.4	90.0	91.6	91.25
1	91.9	92.5	93.1	93.75	94.4	95.0	95.6	96.25	96.9	97.5
2	98.1	98.75	99.4	100.0						

H. Buffer Solutions with pH 9.23-11.02 ($Na_2B_4O_7$-NaOH)

Every given amount of the solution (solution No. 5, p. 253) is brought up to 100 ml with solution No. 8 (*ibid*)

pH	0	1	2	3	4	5	6	7	8	9
9.2	—	—	—	0.72	2.16	3.60	4.90	6.05	7.10	8.05
3	8.90	9.60	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.8
4	15.40	16.0	16.6	17.2	17.7	18.2	18.8	19.4	20.0	20.5
5	21.0	21.6	22.2	22.8	23.4	23.9	24.5	25.1	25.7	26.3
6	26.8	27.4	28.0	28.6	29.2	29.8	30.3	30.8	31.3	31.8
7	32.3	32.8	33.3	33.7	34.1	34.5	34.9	35.3	35.7	36.0
8	36.3	36.6	36.9	37.2	37.5	37.7	38.0	38.3	38.6	38.8
9	39.0	39.3	39.6	39.8	40.0	40.2	40.4	40.6	40.8	40.9
10.0	41.0	41.2	41.4	41.6	41.8	41.9	42.1	42.3	42.5	42.6
1	42.7	42.9	43.1	43.2	43.3	43.4	43.6	43.7	43.8	43.9
2	44.0	44.2	44.3	44.4	44.5	44.6	44.8	44.9	45.0	45.1
3	45.2	45.4	45.5	45.6	45.7	45.8	45.9	46.0	46.1	46.2
4	46.3	46.4	46.5	46.6	46.7	46.8	46.9	46.95	47.05	47.1
5	47.2	47.3	47.35	47.45	47.5	47.6	47.7	47.75	47.85	47.9
6	48.0	48.05	48.1	48.2	48.25	48.3	48.35	48.4	48.5	48.55
7	48.6	48.65	48.7	48.75	48.8	48.85	48.9	48.95	49.0	49.05
8	49.1	49.15	49.2	49.2	49.25	49.3	49.35	49.4	49.4	49.45
9	49.5	49.55	49.6	49.6	49.65	49.7	49.75	49.8	49.8	49.85
11.0	49.9	49.95	50.0							

Table 30 (continued)

I. Buffer Solutions with pH 8.53-12.90 (NH_2CH_2COOH-NaOH)

Every given amount of the solution (solution No. 5, p. 253) is brought up to 100 ml with solution No. 2 (*ibid*)

pH	0	1	2	3	4	5	6	7	8	9
8.5	—	—	—	5.00	5.11	5.22	5.33	5.44	5.56	5.68
6	5.80	5.92	6.04	6.16	6.28	6.41	6.54	6.68	6.82	6.96
7	7.10	7.24	7.38	7.52	7.66	7.81	7.96	8.12	8.28	8.44
8	8.60	8.77	8.94	9.12	9.30	9.48	9.66	9.84	10.02	10.21
9	10.4	10.6	10.8	11.0	11.2	11.4	11.6	11.8	12.0	12.2
9.0	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.3
1	14.6	14.8	15.1	15.3	15.6	15.8	16.0	16.3	16.5	16.8
2	17.0	17.2	17.4	17.6	17.9	18.2	18.5	18.8	19.1	19.4
3	19.7	19.9	20.1	20.3	20.5	20.8	21.1	21.4	21.7	22.0
4	22.3	22.5	22.8	23.1	23.4	23.7	24.0	24.3	24.6	24.9
5	25.2	25.4	25.6	25.9	26.2	26.5	26.8	27.1	27.4	27.7
6	28.0	28.3	28.6	28.9	29.2	29.5	29.8	30.1	30.4	30.7
7	31.0	31.3	31.6	31.9	32.2	32.5	32.8	33.1	33.4	33.6
8	33.8	34.1	34.4	34.7	35.0	35.2	35.4	35.6	35.8	36.0
9	36.2	36.5	36.7	36.9	37.1	37.3	37.5	37.7	37.9	38.1
10.0	38.3	38.5	38.7	38.9	39.1	39.3	39.5	39.7	39.9	40.05
1	40.2	40.4	40.55	40.7	40.9	41.05	41.2	41.4	41.55	41.75
2	41.9	42.05	42.2	42.4	42.55	42.7	42.85	43.0	43.2	43.35
3	43.5	43.65	43.75	43.9	44.0	44.15	44.3	44.4	44.55	44.7
4	44.8	44.9	45.0	45.1	45.2	45.3	45.4	45.5	45.6	45.7
5	45.8	45.9	46.0	46.05	46.15	46.25	46.35	46.45	46.5	46.6
6	46.7	46.75	46.85	46.9	47.0	47.05	47.1	47.2	47.25	47.35
7	47.4	47.45	47.5	47.6	47.65	47.7	47.75	47.8	47.9	47.95
8	48.0	48.05	48.1	48.15	48.2	48.25	48.3	48.35	48.4	48.45
9	48.5	48.55	48.6	48.6	48.65	48.7	48.75	48.8	48.8	48.85
11.0	48.9	48.95	49.0	49.05	49.1	49.15	49.15	49.2	49.25	49.3
1	49.35	49.4	49.45	49.5	49.55	49.6	49.6	49.65	49.7	49.75
2	49.8	49.85	49.9	49.9	49.95	50.0	50.05	50.1	50.1	50.15
3	50.2	50.25	50.3	50.3	50.35	50.4	50.45	50.5	50.5	50.55
4	50.6	50.65	50.7	50.7	50.75	50.8	50.85	50.9	50.9	50.95
5	51.0	51.05	51.1	51.1	51.15	51.2	51.25	51.3	51.3	51.35
6	51.4	51.45	51.5	51.55	51.6	51.65	51.75	51.8	51.85	51.9
7	51.95	52.0	52.1	52.15	52.2	52.25	52.35	52.4	52.45	52.55
8	52.6	52.7	52.75	52.85	52.9	53.0	53.1	53.15	53.25	53.3
9	53.4	53.5	53.6	53.7	53.8	53.9	54.0	54.1	54.2	54.3

Table 30 (continued)

pH	0	1	2	3	4	5	6	7	8	9
12.0	54.45	54.6	54.75	54.85	55.0	55.15	55.25	55.4	55.55	55.65
1	55.8	55.95	56.1	56.3	56.45	56.6	56.75	56.9	57.1	57.25
2	57.4	57.6	57.8	58.0	58.2	58.4	58.6	58.8	59.0	59.2
3	59.4	59.65	59.9	60.1	60.35	60.6	60.85	61.1	61.3	61.55
4	61.8	62.2	62.5	62.9	63.2	63.6	64.0	64.3	64.7	65.0
5	65.4	65.9	66.3	66.8	67.2	67.7	68.2	68.6	69.1	69.5
6	70.0	70.5	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5
7	75.0	75.6	76.2	76.8	77.4	78.0	78.6	79.2	79.8	80.4
8	81.0	81.6	82.3	83.1	84.0	84.9	85.8	86.7	87.7	88.8
9	90.0									

Table 31

Acetic-Acetate Buffer Solutions

To prepare a buffer solution of the required pH value, the given amount of 1*N* acetic acid solution is measured, 50 ml of 1*N* caustic soda solution is added to it, and the mixture is brought up to 500 ml with distilled water.

pH	Acetic acid, 1*N*, ml	pH	Acetic acid, 1*N*, ml	pH	Acetic acid, 1*N*, ml
3.8	421.5	4.67	100.0	5.5	57.4
3.9	345.1	4.7	96.8	5.6	55.9
4.0	284.4	4.8	87.2	5.7	54.7
4.1	236.2	4.9	79.5	5.8	53.7
4.2	197.9	5.0	73.4	5.9	53.0
4.3	167.4	5.1	68.6	6.0	52.3
4.4	143.3	5.2	64.8	6.1	51.9
4.5	124.1	5.3	61.7	6.2	51.5
4.6	108.9	5.4	59.3	6.3	51.2

Table 32

Universal Buffer Mixture

A mixture of phosphoric, acetic and boric acids (0.04*M*, respectively) is prepared. To obtain a buffer solution of the required pH value, the given amount of 0.2*N* NaOH solution is poured into 100 ml of the mixture.

NaOH, 0.2*N*, ml	pH	NaOH, 0.2*N*, ml	pH	NaOH, 0.2*N*, ml	pH	NaOH, 0.2*N*, ml	pH
0	1.81	25.0	4.10	50.0	6.80	75.0	9.62
2.5	1.89	27.5	4.35	52.5	7.00	77.5	9.91
5.0	1.98	30.0	4.56	55.0	7.24	80.0	10.38
7.5	2.09	32.5	4.78	57.5	7.54	82.5	10.88
10.0	2.21	35.0	5.02	60.0	7.96	85.0	11.20
12.5	2.36	37.5	5.33	62.5	8.36	87.5	11.40
15.0	2.56	40.0	5.72	65.0	8.69	90.0	11.58
17.5	2.87	42.5	6.09	67.5	8.95	92.5	11.70
20.0	3.29	45.0	6.37	70.0	9.15	95.0	11.82
22.5	3.78	47.5	6.59	72.5	9.37	100.0	11.98

Table 33

Buffer Solutions from Individual Substances

Substance	pH
Saturated potassium hydrotartrate solution (~0.025*M*) $KHC_4H_4O_6$ (molecular weight: 188.183)	3.59 (16 °C)
Saturated piperazine phosphate* solution (~0.065*M*) $C_4H_{12}N_2HPO_4 \cdot H_2O$ (molecular weight: 202.148)	6.36 (16 °C) 6.34 (18 °C)
0.05*M* sodium tetraborate solution $Na_2B_4O_7 \times \times 10H_2O$ (molecular weight: 381.37)	9.18 (25 °C) 9.07 (38 °C)

---

* Piperazine phosphate is prepared by mixing, at room temperature, equimolecular quantities of piperazine and phosphoric acid with the subsequent crystallization of separated white lamellar crystals.

Table 34

Determination of Electrode Potentials

For the reaction

$$Me^{n+} + ne \rightleftharpoons Me^0,$$

the mathematical expression of the potential value of the metallic electrode immersed into a solution containing its ions is determined by the formula:

$$E_{Me^{n+}/Me^0} = E^0_{Me^{n+}/Me^0} + \frac{RT}{nF} \ln a_{Me^{n+}}$$

For an oxidation-reduction reaction with the participation of hydrogen ions

$$a\ \mathrm{Ox.} + m\ H^+ + ne \rightleftharpoons b\ \mathrm{Red.} + \frac{m}{2}\ H_2O$$

the potential value of an electrode from platinum or other noble metal immersed into a solution of a mixture of oxidized and reduced forms of a given compound is determined by the formula:

$$E_{\mathrm{Ox./Red.}} = E^0_{\mathrm{Ox./Red.}} + \frac{RT}{nF} \ln \frac{a^a_{\mathrm{Ox.}}}{a^b_{\mathrm{Red.}}}\, a^m_{H^+}$$

If hydrogen ions do not participate in the given reaction, the expression assumes the following form:

$$E_{\mathrm{Ox./Red.}} = E^0_{\mathrm{Ox./Red.}} + \frac{RT}{nF} \ln \frac{a^a_{\mathrm{Ox.}}}{a^b_{\mathrm{Red.}}}$$

In all these formulas

E = electrode potential

E^0 = constant value which is characteristic of the given reaction (standard electrode potential)

R = gas constant

T = absolute temperature

n = number of electrons participating in the reaction

F = Faraday's constant (96 500 coulombs)

$a_{Me^{n+}}$, $a_{\mathrm{Ox.}}$, $a_{\mathrm{Red.}}$, a_{H^+} = activities of the components participating in the reaction

a, b, m = stoichiometric coefficients of the components participating in the reaction.

In going over from natural to common logarithms, we obtain (when $n = 1$)

$$E_{\mathrm{Ox./Red.}} = E^0_{\mathrm{Ox./Red.}} + \vartheta \log \frac{a^a_{\mathrm{Ox.}}}{a^b_{\mathrm{Red.}}}\, a^m_{H^+}$$

Table 34 (continued)

The values of ϑ, equal to 0.0591 + 0.0002 (t — 25 °C), are given in Table 34,A, for temperatures ranging from 0 °C to 50 °C.

When $a_{\text{Ox.}}$, $a_{\text{Red.}}$ and a_{H^+} or $a_{\text{Me}^{n+}}$ are equal to unity

$$E = E^0$$

In accepted usage, E^0 is called the standard electrode potential. The oxidation-reduction system is represented as a reduction reaction:

$$\text{Ox.} + ne \rightarrow \text{Red.} \quad \text{or} \quad \text{Me}^{n+} + ne \rightarrow \text{Me}\downarrow$$

The potential of a single isolated electrode cannot be measured, and therefore the electromotive force (emf) of an electrochemical cell consisting of two half-cells is measured; the value of the emf is equal to the difference of the electrode potentials of the two half-cells. If electrochemical cells are always formed with the same electrode whose potential remains constant and with various other electrodes, then upon measuring the emf, the value of the electrode potentials of the oxidation-reduction systems can be found relative to the potential of the selected electrode, which in the given case serves as a reference electrode (E_{ref}).

The standard hydrogen electrode (SHE) is used as a reference electrode. It consists of a platinized platinum electrode immersed into an acid solution having $a_{\text{H}^+} = 1$ (1N H_2SO_4 solution) at a pressure of purified hydrogen gas equal to 1 atm. The potential of the standard hydrogen electrode ($E^0_{\text{H}^+/\text{H}_2}$) is conventionally taken as zero at any temperature.

The standard potentials (E^0) of various oxidation-reduction (redox) systems relative to the potential of the standard hydrogen electrode are given in Table 40 (p. 300). The "+" and "—" signs of these potentials show the direction in which reaction occurs at the electrodes in question (provided that they are in the standard state) when they form a galvanic cell with a standard hydrogen electrode.

A minus (—) sign of the potential value indicates that the spontaneous reaction occurring at the electrode in question is the oxidation of the reduced form of the redox couple, and a plus (+) sign, the reduction of the oxidized form.

In practice, it is easier to work not with a hydrogen electrode, but with other reference electrodes whose potentials are constant and determined relative to E_{SHE}. Table 34,B (p. 268) gives the compositions and potentials (E_{ref}) of the most commonly used reference electrodes.

When calculating the electrode potential of a redox system (E_x) according to the result of the measurement of the emf of the galvanic cell in which the second electrode is one of the reference electrodes (see Table 34,B, p. 268), account must be taken of the sign of the electrode being examined. When the spontaneous reaction at the electrode in question is oxidation (i.e., when the electrode potential has a negative sign), then

$$\text{emf} = E_{\text{ref}} - E_x$$

Table 34 (continued)

or, conversely, when this reaction is reduction, then

$$\text{emf} = E_x - E_{\text{ref}}$$

Hence, in the first case,

$$E_x = E_{\text{ref}} - \text{emf}$$

and in the second,

$$E_x = E_{\text{ref}} + \text{emf}$$

For example, the measured emf of a galvanic cell consisting of a saturated reference calomel electrode ($E_{\text{Sat.CE.}} = 0.247$ V, see Table 35,B, p. 271) and a zinc electrode immersed in a solution (in which $a_{\text{Zn}^{2+}} = 1$) has an absolute value of 1.007 V. Since, in such a galvanic cell, the spontaneous reaction is the oxidation of metallic zinc ("—" sign):

$$\text{Zn}\downarrow - 2e \rightarrow \text{Zn}^{2+}$$

consequently:

$$E^0_{\text{Zn}^{2+}/\text{Zn}} = E_{\text{ref}} - \text{emf} = 0.247 - 1.007 = -0.760 \text{ V}$$

If an electrochemical cell consists of a saturated reference calomel electrode and a platinum electrode immersed into an iron salt solution having $a_{\text{Fe}^{3+}} = a_{\text{Fe}^{2+}} = 1$, then the emf value of this cell is $+0.524$ V. Since the spontaneous reaction at the electrode being considered is reduction ("+" sign), iron (III) is reduced to iron (II):

$$\text{Fe}^{3+} + e = \text{Fe}^{2+}$$

then

$$E^0_{\text{Fe}^{3+}/\text{Fe}^{2+}} = E_{\text{ref}} + \text{emf} = 0.247 + 0.524 = 0.771 \text{ V}$$

A. Values of ϑ at $n = 1$ and Temperatures Ranging from 0 °C to 50 °C

($\vartheta = 0.0001983T = 0.0591 + 0.0002\,(t - 25\,°\text{C})$)

Temperature, °C	ϑ	log ϑ	Temperature, °C	ϑ	log ϑ	Temperature, °C	ϑ	log ϑ
0	0.0541	73 320	8	0.0557	74 586	16	0.0573	75 815
1	0.0543	73 480	9	0.0559	74 741	17	0.0575	75 967
2	0.0545	73 640	10	0.0561	74 896	18	0.0577	76 118
3	0.0547	73 799	11	0.0563	75 051	19	0.0579	76 268
4	0.0549	73 957	12	0.0565	75 205	20	0.0581	76 418
5	0.0551	74 115	13	0.0567	75 358	21	0.0583	76 567
6	0.0553	74 273	14	0.0569	75 511	22	0.0585	76 716
7	0.0555	74 429	15	0.0571	75 664	23	0.0587	76 864

Table 34 (continued)

Temperature, °C	ϑ	log ϑ	Temperature, °C	ϑ	log ϑ	Temperature, °C	ϑ	log ϑ
24	0.0589	77 012	33	0.0607	78 319	42	0.0625	79 588
25	0.0591	77 159	34	0.0609	78 462	43	0.0627	79 727
26	0.0593	77 305	35	0.0611	78 604	44	0.0629	79 865
27	0.0595	77 452	36	0.0613	78 746	45	0.0631	80 003
28	0.0597	77 597	37	0.0615	78 888	46	0.0633	80 140
29	0.0599	77 743	38	0.0617	79 029	47	0.0635	80 277
30	0.0601	77 887	39	0.0619	79 169	48	0.0637	80 414
31	0.0603	78 032	40	0.0621	79 309	49	0.0639	80 550
32	0.0605	78 176	41	0.0623	79 449	50	0.0641	80 686

B. Composition and Potential of Selected Reference Electrodes Relative to the Standard Hydrogen Electrode (at 20 °C)

Reference electrode	Composition of reference electrode	Potential E_{ref}, V
Standard hydrogen electrode (SHE) Pt, H_2 | H^+ |	Platinized platinum plate in 1*M* H_2SO_4 solution, saturated with H_2 under a pressure of 1 atm	0.000
Mercuriodide electrode (MIE) Hg | HgI_2, KI, KCl |	Metallic mercury, 4.2 g of KI and 1.3 g of HgI_2 in 100 ml of saturated KCl solution	+0.02
Chlorosilver electrode (CSE) Ag | AgCl, Cl^- |	Metallic silver, coated with a layer of AgCl, in an HCl or KCl solution having the following concentrations:	
	0.1*N*	+0.290
	1.0*N*	+0.237
Calomel electrodes (CE) Hg | Hg_2Cl_2, KCl |	Metallic mercury, paste of metallic mercury and Hg_2Cl_2 in a KCl solution having the following concentrations:	
0.1 (0.1 SCE)	0.1*N*	+0.337
1.0 (SCE)	1.0*N*	+0.284
3.5 (3.5 SCE)	3.5*N*	+0.250
Saturated electrode (Sat.CE)	Saturated	+0.247
Mercurosulphate electrode (MSE) Hg | Hg_2SO_4, H_2SO_4 |	Metallic mercury, paste of metallic mercury and Hg_2SO_4 in 2*N* H_2SO_4 solution	+0.682

Table 35

Electrometric Determination of pH

The hydrogen ion exponent pH = $-\log a_{H^+}$. In the electrometric determination of the pH, the emf of one of the following cells is measured.

(1) Indicator electrode: hydrogen electrode; reference electrode: SHE*. Then,

$$\text{emf} = E_{SHE} - E_{2H^+/H_2}$$

Since $E_{SHE} = 0$ and

$$E_{2H^+/H_2} = \vartheta \log a_{H^+} = -\vartheta \text{pH}$$

then

$$\text{pH} = \frac{\text{emf}}{\vartheta}$$

(2) Indicator electrode: hydrogen electrode; reference electrode: one of the calomel electrodes (CE). Then,

$$\text{emf} = E_{CE} - E_{2H^+/H_2}$$

hence,

$$\text{emf} = E_{CE} + \vartheta \text{pH}$$

and

$$\text{pH} = \frac{\text{emf} - E_{CE}}{\vartheta}$$

(3) Indicator electrode: quinhydrone electrode; reference electrode: SHE. Then,

$$\text{emf} = E_{\text{quin./hydr.}} - E_{SHE}$$

$$E_{\text{quin./hydr.}} = E^0_{\text{quin./hydr.}} + \vartheta \log a_{H^+} = E^0_{\text{quin./hydr.}} - \vartheta \text{ pH}$$

hence,

$$\text{emf} = E^0_{\text{quin./hydr.}} - \vartheta \text{ pH} - E_{SHE}$$

Since $E_{SHE} = 0$, then

$$\text{pH} = \frac{E^0_{\text{quin./hydr.}} - \text{emf}}{\vartheta}$$

(4) Indicator electrode: quinhydrone; reference electrode: CE. Then,

$$\text{emf} = E^0_{\text{quin./hydr.}} - E_{CE}$$

hence

$$\text{emf} = E^0_{\text{quin./hydr.}} - \vartheta \text{ pH} - E_{CE}$$

---

* Standard hydrogen electrode.

Table 35 (continued)

and

$$\mathrm{pH}=\frac{E^0_{\mathrm{quin./hydr.}}-E_{\mathrm{CE}}-\mathrm{emf}}{\vartheta}$$

The values of $E^0_{\mathrm{quin./hydr.}}$, E_{CE} and $E^0_{\mathrm{quin./hydr.}}-E_{\mathrm{CE}}$ at different temperatures are given in Table 35,A (p. 270), 35,B (p. 271) and 35,C (p. 272).

When the pH is being found by methods (3) and (4), account must be taken of what was said on p. 266. As the pH value increases, the $E_{\mathrm{quin./hydr.}}$ potential decreases. The latter can decrease by so much that the spontaneous reaction at the quinhydrone electrode will be the oxidation of hydroquinone into quinone ("—" sign). Then, the calculating formulas change accordingly:

for method (3):

$$\mathrm{emf}=E_{\mathrm{SHE}}-E_{\mathrm{quin./hydr.}}=-(E^0_{\mathrm{quin./hydr.}}-\vartheta\,\mathrm{pH})=$$
$$=\vartheta\,\mathrm{pH}-E^0_{\mathrm{quin./hydr.}}$$

$$\mathrm{pH}=\frac{\mathrm{emf}+E^0_{\mathrm{quin./hydr.}}}{\vartheta}$$

for method (4):

$$\mathrm{emf}=E_{\mathrm{CE}}-E_{\mathrm{quin./hydr.}}=E_{\mathrm{CE}}-(E^0_{\mathrm{quin./hydr.}}-\vartheta\,\mathrm{pH})=$$
$$=E_{\mathrm{CE}}+\vartheta\,\mathrm{pH}-E^0_{\mathrm{quin./hydr.}}$$

$$\mathrm{pH}=\frac{\mathrm{emf}+E^0_{\mathrm{quin./hydr.}}-E_{\mathrm{CE}}}{\vartheta}$$

A. Standard Quinhydrone Electrode Potential ($E^0_{\mathrm{quin./hydr.}}$) at Temperatures Ranging from 0 °C to 50 °C, $E^0_{\mathrm{quin./hydr.}}=0.7175-0.00074t$, V

Temperature, °C	$E^0_{\mathrm{quin./hydr.}}$, V	Temperature, °C	$E^0_{\mathrm{quin./hydr.}}$, V	Temperature, °C	$E^0_{\mathrm{quin./hydr.}}$, V
0	0.7175	9	0.7108	18	0.7042
1	0.7168	10	0.7101	19	0.7034
2	0.7160	11	0.7094	20	0.7027
3	0.7153	12	0.7086	21	0.7020
4	0.7145	13	0.7079	22	0.7012
5	0.7138	14	0.7071	23	0.7005
6	0.7131	15	0.7064	24	0.6997
7	0.7123	16	0.7057	25	0.6990
8	0:7116	17	0.7049	26	0.6983

Table 35 (continued)

Temperature, °C	$E^0_{\text{quin./hydr.}}$, V	Temperature, °C	$E^0_{\text{quin./hydr.}}$, V	Temperature, °C	$E^0_{\text{quin./hydr.}}$, V
27	0.6975	35	0.6916	43	0.6857
28	0.6968	36	0.6909	44	0.6849
29	0.6960	37	0.6901	45	0.6842
30	0.6953	38	0.6894	46	0.6835
31	0.6946	39	0.6886	47	0.6827
32	0.6938	40	0.6879	48	0.6820
33	0.6931	41	0.6872	49	0.6812
34	0.6923	42	0.6864	50	0.6805

B. Potentials of Calomel Electrodes at Temperatures Ranging from 0 °C to 50 °C

$$E_{0.1\text{SCE}} = 0.3365 - 0.00006\,(25 - t)\ \text{V}$$

$$E_{\text{SCE}} = 0.2828 - 0.00024\,(25 - t)\ \text{V}$$

$$E_{\text{Sat.CE}} = 0.2438 - 0.00065\,(25 - t)\ \text{V}$$

Temperature, °C	Potential, V			Temperature, °C	Potential, V		
	$E_{0.1\text{SCE}}$	E_{SCE}	$E_{\text{Sat.CE}}$		$E_{0.1\text{SCE}}$	E_{SCE}	$E_{\text{Sat.CE}}$
0	0.3380	0.2888	0.2601	19	0.3369	0.2842	0.2477
1	0.3379	0.2886	0.2594	20	0.3368	0.2840	0.2471
2	0.3379	0.2883	0.2588	21	0.3367	0.2838	0.2464
3	0.3378	0.2881	0.2581	22	0.3367	0.2835	0.2458
4	0.3378	0.2878	0.2575	23	0.3366	0.2833	0.2451
5	0.3377	0.2876	0.2568	24	0.3366	0.2830	0.2445
6	0.3376	0.2874	0.2562	25	0.3365	0.2828	0.2438
7	0.3376	0.2871	0.2555	26	0.3364	0.2826	0.2431
8	0.3375	0.2869	0.2549	27	0.3364	0.2823	0.2425
9	0.3375	0.2866	0.2542	28	0.3363	0.2821	0.2418
10	0.3374	0.2864	0.2536	29	0.3363	0.2818	0.2412
11	0.3373	0.2862	0.2529	30	0.3362	0.2816	0.2405
12	0.3373	0.2859	0.2523	31	0.3361	0.2814	0.2399
13	0.3372	0.2857	0.2516	32	0.3361	0.2811	0.2393
14	0.3372	0.2854	0.2510	33	0.3360	0.2809	0.2386
15	0.3371	0.2852	0.2503	34	0.3360	0.2806	0.2379
16	0.3370	0.2850	0.2497	35	0.3359	0.2804	0.2373
17	0.3370	0.2847	0.2490	36	0.3358	0.2802	0.2366
18	0.3369	0.2845	0.2483	37	0.3358	0.2799	0.2360

Table 35 (continued)

Temperature, °C	Potential, V			Temperature, °C	Potential, V		
	$E_{0.1\text{SCE}}$	E_{SCE}	$E_{\text{Sat.CE}}$		$E_{0.1\text{SCE}}$	E_{SCE}	$E_{\text{Sat.CE}}$
38	0.3357	0.2797	0.2353	45	0.3353	0.2780	0.2308
39	0.3357	0.2794	0.2347	46	0.3352	0.2778	0.2301
40	0.3356	0.2792	0.2340	47	0.3352	0.2775	0.2295
41	0.3355	0.2790	0.2334	48	0.3351	0.2773	0.2288
42	0.3355	0.2787	0.2327	49	0.3351	0.2770	0.2282
43	0.3354	0.2785	0.2321	50	0.3350	0.2768	0.2275
44	0.3354	0.2782	0.2314				

C. Difference between the Standard Quinhydrone Electrode Potential ($E^0_{\text{quin./hydr.}}$) and the Potentials of the Reference Calomel Electrodes (E_{CE}) at Temperatures Ranging from 0 °C to 50 °C ($E^0_{\text{quin./hydr.}} - E_{\text{CE}}$)

Temperature, °C	$E^0_{\text{quin./hydr.}} - E_{0.1\,\text{SCE}}$	$E^0_{\text{quin./hydr.}} - E_{\text{SCE}}$	$E^0_{\text{quin./hydr.}} - E_{\text{Sat.CE}}$	Temperature, °C	$E^0_{\text{quin./hydr.}} - E_{0.1\,\text{SCE}}$	$E^0_{\text{quin./hydr.}} - E_{\text{SCE}}$	$E^0_{\text{quin./hydr.}} - E_{\text{Sat.CE}}$
0	0.3795	0.4287	0.4575	26	0.3618	0.4157	0.4551
1	0.3788	0.4282	0.4574	27	0.3611	0.4152	0.4550
2	0.3781	0.4277	0.4573	28	0.3605	0.4147	0.4549
3	0.3775	0.4272	0.4572	29	0.3598	0.4142	0.4548
4	0.3768	0.4267	0.4571	30	0.3591	0.4137	0.4548
5	0.3761	0.4262	0.4570	31	0.3584	0.4132	0.4547
6	0.3754	0.4257	0.4569	32	0.3577	0.4127	0.4546
7	0.3747	0.4252	0.4568	33	0.3571	0.4122	0.4545
8	0.3741	0.4247	0.4567	34	0.3564	0.4117	0.4544
9	0.3734	0.4242	0.4566	35	0.3557	0.4112	0.4543
10	0.3727	0.4237	0.4566	36	0.3550	0.4107	0.4542
11	0.3720	0.4232	0.4565	37	0.3543	0.4102	0.4541
12	0.3713	0.4227	0.4564	38	0.3537	0.4097	0.4540
13	0.3707	0.4222	0.4563	39	0.3530	0.4092	0.4539
14	0.3700	0.4217	0.4562	40	0.3523	0.4087	0.4539
15	0.3693	0.4212	0.4561	41	0.3516	0.4082	0.4538
16	0.3686	0.4207	0.4560	42	0.3509	0.4077	0.4537
17	0.3679	0.4202	0.4559	43	0.3503	0.4072	0.4536
18	0.3673	0.4197	0.4558	44	0.3496	0.4067	0.4535
19	0.3666	0.4192	0.4557	45	0.3489	0.4062	0.4534
20	0.3659	0.4187	0.4557	46	0.3482	0.4057	0.4533
21	0.3652	0.4182	0.4556	47	0.3475	0.4052	0.4532
22	0.3645	0.4177	0.4555	48	0.3469	0.4047	0.4531
23	0.3639	0.4172	0.4554	49	0.3462	0.4042	0.4530
24	0.3632	0.4167	0.4553	50	0.3455	0.4037	0.4530
25	0.3625	0.4162	0.4552				

Table 36

Change of pH in Precipitation of Metal Hydroxides (Approximate Values with Account Taken of the Formation of Hydroxocomplexes)*

Hydroxide	pH values				
	beginning of precipitation with the initial concentration of the ion being precipitated equal to		complete precipitation (residual concentration being less than 10^{-5} *M*)	beginning of dissolution of the precipitate (precipitation ceases to be complete)	complete dissolution of the precipitate
	1*M*	0.01*M*			
$Sn(OH)_4$	0	0.5	1	13	15
$TiO(OH)_2$	0	0.5	2.0	—	—
$Sn(OH)_2$	0.9	2.1	4.7	10	13.5
$ZrO(OH)_2$	1.3	2.25	3.75	—	—
HgO	1.3	2.4	5.0	11.5	—
$Fe(OH)_3$	1.5	2.3	4.1	14	—
$Al(OH)_3$	3.3	4.0	5.2	7.8	10.8
$Cr(OH)_3$	4.0	4.9	6.8	12	15
$Be(OH)_2$	5.2	6.2	8.8	—	—
$Zn(OH)_2$	5.4	6.4	8.0	10.5	12-13
Ag_2O	6.2	8.2	11.2	12.7	—
$Fe(OH)_2$	6.5	7.5	9.7	13.5	—
$Co(OH)_2$	6.6	7.6	9.2	14.1	—
$Ni(OH)_2$	6.7	7.7	9.5	—	—
$Cd(OH)_2$	7.2	8.2	9.7	—	—
$Mn(OH)_2$	7.8	8.8	10.4	14	—
$Mg(OH)_2$	9.4	10.4	12.4	—	—

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* It should be noted that when hydroxides are being precipitated by an addition of an alkaline solution to a corresponding salt solution, a local growth in the pH value and the precipitate amount occur in places where the precipitant drops fall. Upon stirring, a back dissolution of the precipitate formed does not often take place (see Table 10 for various values of the solubility products of hydroxides during precipitation and after some ageing).

Table 37

Ionization Constants of Chief Acids and Bases

The table gives the thermodynamic ionization constants of acids and bases at 25 °C:

$$K_a = \frac{a_{H^+} a_{A^-}}{a_{HA}} = \frac{[H^+][A^-]}{[HA]} \times \frac{f_{H^+} f_{A^-}}{f_{HA}}$$

$$K_b = \frac{a_{Ct^+} a_{OH^-}}{a_{CtOH}} = \frac{[Ct^+][OH^-]}{[CtOH]} \times \frac{f_{Ct^+} f_{OH^-}}{f_{CtOH}}$$

where a_{H^+}, a_{A^-}, etc. = activities of ions or molecules
$[H^+]$, $[A^-]$, etc. = concentrations of ions or molecules
f_{H^+}, f_{A^-}, f_{Ct^+}, etc. = activity coefficients of ions or molecules.

Acids

Name	Formula	K_a	pK_a
Acetic	CH_3COOH	1.74×10^{-5}	4.76
Acid Chrome Black	*See* Table 28,		
Special K_1	No. 1 (p. 220)	5.0×10^{-7}	6.3
K_2		2.8×10^{-12}	11.55
Acrylic	$CH_2{=}CHCOOH$	5.5×10^{-5}	4.26
Adipic K_1	$HOOC(CH_2)_4COOH$	3.9×10^{-5}	4.26
K_2		5.1×10^{-6}	5.30
Aminoacetic (Glycine)	NH_2CH_2COOH	1.7×10^{-10}	9.78
α-Aminopropionic (α-Alanine)	$CH_3CH(NH_2)COOH$	1.35×10^{-10}	9.87

Table 37 (continued)

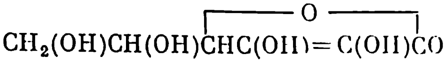
Name	Formula	K_a	pK_a
β-Aminopropionic (β-Alanine)	$NH_2(CH_2)_2COOH$	5.9×10^{-11}	10.23
Antimonic	$H[Sb(OH)_6]$	4.0×10^{-5}	4.4
Arsenic K_1	H_3AsO_4	6.0×10^{-3}	2.22
K_2		1.05×10^{-7}	6.98
K_3		2.95×10^{-12}	11.53
Arsenous	H_3AsO_3	5.1×10^{-10}	9.29
Ascorbic K_1	 $CH_2(OH)CH(OH)\overbrace{CHC(OH)=C(OH)CO}^{O}$	9.1×10^{-5}	4.04
K_2		4.6×10^{-12}	11.34
Azelaic K_1	$HOOC(CH_2)_7COOH$	2.9×10^{-5}	4.54
K_2		2.8×10^{-6}	5.55
Benzoic	C_6H_5COOH	6.2×10^{-5}	4.21
Boric (ortho-) K_1	H_3BO_3	5.8×10^{-10}	9.24
Boric (tetra-) K_1	$H_2B_4O_7$	1.8×10^{-4}	3.74
K_2		2.0×10^{-8}	7.70
Bromous	$HBrO$	2.5×10^{-9}	8.60
Butyric (*iso*)	$(CH_3)_2CHCOOH$	1.4×10^{-5}	4.86
Butyric (normal)	$CH_3CH_2CH_2COOH$	1.5×10^{-5}	4.82
Caproic	$CH_3(CH_2)_4COOH$	1.31×10^{-5}	4.88
Caprylic	$CH_3(CH_2)_6COOH$	1.28×10^{-5}	4.89
Carbonic K_1	CO_2 (aq.) $+ H_2O$	4.5×10^{-7}	6.35
K_2		4.8×10^{-11}	10.32
Chloroacetic	$CH_2ClCOOH$	1.4×10^{-3}	2.86
Chlorous	$HClO_2$	1.1×10^{-2}	1.97

Table 37 (continued)

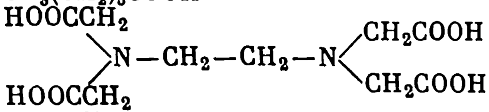
Name	Formula	K_a	pK_a
Chromic K_1	H_2CrO_4	1.1×10^{-1}	0.98
K_2		3.2×10^{-7}	6.50
Chromotropic K_1	$C_{10}H_6(OH)_2(SO_3H)_2$	4.4×10^{-6}	5.36
K_2		2.5×10^{-16}	15.6
Cinnamic (*cis*-)	$C_6H_5CH{=}CHCOOH$	1.3×10^{-4}	3.88
Cinnamic (*trans*-)	$C_6H_5CH{=}CHCOOH$	3.7×10^{-5}	4.43
Citric K_1	$HOOCCH_2C(OH)(COOH)CH_2COOH$	7.4×10^{-4}	3.13
K_2		1.8×10^{-5}	4.76
K_3		4.0×10^{-7}	6.40
m-Cresol	$CH_3C_6H_4OH$	9.8×10^{-11}	10.01
o-Cresol	$CH_3C_6H_4OH$	6.3×10^{-11}	10.20
p-Cresol	$CH_3C_6H_4OH$	6.7×10^{-11}	10.17
Crotonic (β-methylacrylic)	$CH_3{-}CH{=}CHCOOH$	2.0×10^{-5}	4.70
Cyanic	$HCNO$	3.5×10^{-4}	3.46
Dichloroacetic	$CHCl_2COOH$	5.0×10^{-2}	1.30
Dichromic K_2	$H_2Cr_2O_7$	2.3×10^{-2}	1.64
Dimolybdenic	$H_2Mo_2O_7$	9.55×10^{-6}	5.02
Dithionic K_1	$H_2S_2O_6$	6.3×10^{-1}	0.2
K_2		4.0×10^{-4}	3.4
Dithionous (*see* Hyposulphurous)			
Enanthic	$CH_3(CH_2)_5COOH$	1.3×10^{-5}	4.89
Ethylenediamine tetraacetic K_1	 $(HOOCCH_2)_2N{-}CH_2{-}CH_2{-}N(CH_2COOH)_2$	1.0×10^{-2}	1.99
K_2		2.1×10^{-3}	2.67
K_3		5.4×10^{-7}	6.27
K_4		1.1×10^{-11}	10.95
Ferrocyanide K_3	$H_4Fe(CN)_6$	2.7×10^{-3}	2.57
K_4		4.5×10^{-5}	4.35

Table 37 (continued)

Name	Formula	K_a	pK_a
Fluorophosphoric K_1	$H_2[PO_3F]$	2.8×10^{-1}	0.55
K_2		1.6×10^{-5}	4.80
Formic	$HCOOH$	1.8×10^{-4}	3.75
Fumaric K_1	$HOOCHC{=}CHCOOH$	9.3×10^{-4}	3.03
K_2		4.2×10^{-5}	4.38
Gallic	$C_6H_2(OH)_3COOH$	3.9×10^{-5}	4.41
Germanic K_1	H_4GeO_4	1.7×10^{-9}	8.78
K_2		2.0×10^{-13}	12.7
Gluconic	$CH_2OH(CHOH)_4COOH$	1.4×10^{-4}	3.86
Glutaminic K_1	$HOOC(CH_2)_2CH(NH_2)COOH$	4.7×10^{-5}	4.33
K_2		1.2×10^{-10}	9.92
Glutaric K_1	$HOOC(CH_2)_3COOH$	4.6×10^{-5}	4.34
K_2		5.4×10^{-6}	5.27
Glyceric	$CH_2(OH)CH(OH)COOH$	3.0×10^{-4}	3.52
Glycolic	$CH_2(OH)COOH$	1.3×10^{-4}	3.88
Hydrazoic	HN_3	1.9×10^{-5}	4.72
Hydrofluoric	HF	6.8×10^{-4}	3.17
Hydrogen cyanide	HCN	6.2×10^{-10}	9.21
Hydrogen peroxide	H_2O_2	2.0×10^{-12}	11.70
Hydrogen superoxide	HO_2	6.3×10^{-3}	2.2
Hydroquinone	$C_6H_4(OH)_2$ (1,4)	1.1×10^{-10}	9.96
Hydroselenious K_1	H_2Se	1.3×10^{-4}	3.89
K_2		1.0×10^{-11}	11.0
Hydrosulphuric K_1	H_2S	1.0×10^{-7}	6.99
K_2		1.3×10^{-13}	12.89
Hydrotellurous K_1	H_2Te	2.3×10^{-3}	2.64
K_2		1×10^{-11}	11

Table 37 (*continued*)

Name	Formula	K_a	pK_a
8-Hydroxyquinoline	C_9H_7ON	1.3×10^{-10}	9.90
Hypochlorous	$HClO$	5.0×10^{-8}	7.30
Hypoiodous	HIO	2.3×10^{-11}	10.64
Hyponitrous K_1	$H_2N_2O_2$	6.2×10^{-8}	7.21
K_2		2.9×10^{-12}	11.54
Hypophosphoric K_1	$H_4P_2O_6$	6.3×10^{-3}	2.20
K_2		1.6×10^{-3}	2.81
K_3		5.4×10^{-8}	7.27
K_4		9.3×10^{-11}	10.03
Hypophosphorous	H_3PO_2	5.9×10^{-2}	1.23
Hyposulphurous (dithionous) K_2	$H_2S_2O_4$	3.55×10^{-3}	2.45
Iodic	HIO_3	1.6×10^{-1}	0.79
Lactic	$CH_3CH(OH)COOH$	1.4×10^{-4}	3.86
Maleic K_1	$HOOCCH{=}CHCOOH$	1.2×10^{-2}	1.92
K_2		5.9×10^{-7}	6.23
Malic K_1	$HOOCCH(OH)CH_2COOH$	3.5×10^{-4}	3.46
K_2		8.9×10^{-6}	5.05
Malonic K_1	$HOOCCH_2COOH$	1.4×10^{-3}	2.85
K_2		2.0×10^{-6}	5.70
Mandelic	$C_6H_5CH(OH)COOH$	3.9×10^{-4}	3.41
Manganic K_1	H_2MnO_4	$\sim 10^{-1}$	~ 1
K_2		7.1×10^{-11}	10.15
Molybdenic K_1	H_2MoO_4	2.9×10^{-3}	2.54
K_2		1.4×10^{-4}	3.86
m-Nitrobenzoic	$NO_2C_6H_4COOH$	3.5×10^{-4}	3.45
o-Nitrobenzoic	$NO_2C_6H_4COOH$	6.8×10^{-3}	2.17
p-Nitrobenzoic	$NO_2C_6H_4COOH$	3.6×10^{-4}	3.44

Table 37 (continued)

Name	Formula	K_a	pK_a
Nitrous	HNO_2	5.1×10^{-4}	3.29
Oxalic K_1	$H_2C_2O_4$	5.6×10^{-2}	1.25
K_2		5.4×10^{-5}	4.27
Periodic K_1	HIO_4; H_5IO_6	2.8×10^{-2}	1.55
K_2		5.4×10^{-9}	8.27
K_3		1.05×10^{-15}	14.98
Phenol	C_6H_5OH	1.0×10^{-10}	10.0
Phosphoric (ortho) K_1	H_3PO_4	7.6×10^{-3}	2.12
K_2		6.2×10^{-8}	7.21
K_3		4.2×10^{-13}	12.38
Phosphoric (pyro) K_1	$H_4P_2O_7$	3.0×10^{-2}	1.52
K_2		2.3×10^{-3}	2.64
K_3		2.0×10^{-7}	6.70
K_4		4.3×10^{-10}	9.37
Phosphorous K_1	H_3PO_3	1.6×10^{-2}	1.80
K_2		2.0×10^{-7}	6.70
m-Phthalic K_1	$C_6H_4(COOH)_2$	2.0×10^{-4}	3.70
K_3		2.5×10^{-5}	4.60
o-Phthalic K_1	$C_6H_4(COOH)_2$	1.1×10^{-3}	2.95
K_2		4.0×10^{-6}	5.40
p-Phthalic K_1	$C_6H_4(COOH)_2$	2.9×10^{-4}	3.54
K_2		3.5×10^{-5}	4.46
Picric	$HOC_6H_2(NO_2)_3$	5.1×10^{-1}	0.29
Propionic	CH_3CH_2COOH	1.35×10^{-5}	4.87
Pyrocatechin K_1	$C_6H_4(OH)_2(1,2)$	3.6×10^{-10}	9.45
Resorcinol	$C_6H_4(OH)_2(1,3)$	3.6×10^{-10}	9.44
Salicylic	$C_6H_4(OH)COOH$	1.1×10^{-3}	2.97

Table 37 (continued)

Name	Formula	K_a	pK_a
Sebacic K_1	$HOOC(CH_2)_8COOH$	4.0×10^{-5}	4.40
K_2		6.0×10^{-6}	5.22
Selenic K_2	H_2SeO_4	1.3×10^{-2}	1.88
Selenious K_1	H_2SeO_3	2.4×10^{-3}	2.62
K_2		4.8×10^{-9}	8.32
Silicic (ortho-) K_1	H_4SiO_4	1.3×10^{-11}	9.9
K_2		1.6×10^{-12}	11.8
K_3		2.0×10^{-14}	13.7
Succinic K_1	$HOOCCH_2CH_2COOH$	1.6×10^{-5}	4.21
K_2		2.3×10^{-6}	5.63
Sulphamic	H_2NSO_3H	1.05×10^{-1}	0.98
Sulphanilic	$H_2NC_6H_4SO_3H$	6.3×10^{-4}	3.20
Sulphosalicylic K_2	$C_6H_3(OH)(COOH)SO_3H$	1.4×10^{-3}	2.86
K_3		1.8×10^{-12}	11.74
Sulphuric K_2	H_2SO_4	1.2×10^{-2}	1.94
Sulphurous K_1	H_2SO_3	1.7×10^{-2}	1.76
K_2		6.2×10^{-8}	7.20
Tartaric K_1	$HOOCCH(OH)CH(OH)COOH$	9.1×10^{-4}	3.04
K_2		4.3×10^{-5}	4.37
Telluric K_1	H_6TeO_6	2.0×10^{-8}	7.70
K_2		1.1×10^{-11}	10.95
K_3		1×10^{-15}	15
Tellurous K_1	H_2TeO_3	2.7×10^{-3}	2.57
K_2		1.8×10^{-8}	7.74
Thiocyanic	$HSCN$	1.4×10^{-1}	0.85
Thiosulphuric K_1	$H_2S_2O_3$	2.5×10^{-1}	0.60
K_2		1.9×10^{-2}	1.72

Table 37 (continued)

Name	Formula	K_a	pK_a
Trichloroacetic	CCl_3COOH	2.0×10^{-1}	0.70
Tungstic	H_2WO_4	6.3×10^{-5}	4.2
Valeric (*iso*-)	$(CH_3)_2CHCH_2COOH$	1.7×10^{-5}	4.78
Valeric (normal)	$CH_3(CH_2)_3COOH$	1.4×10^{-5}	4.86
Vanadic (ortho-) K_2	H_3VO_4	1.1×10^{-9}	8.95
K_3		4.0×10^{-15}	14.4

Bases

Name	Formula	K_b	pK_b
Ammonia solution	$NH_3 + H_2O$	1.76×10^{-5}	4.755
Aniline	$C_6H_5NH_2 + H_2O$	4.2×10^{-10}	9.38
Barium hydroxide K_2	$Ba(OH)_2$	2.3×10^{-1}	0.64
Benzidine K_1	$H_2NC_6H_4C_6H_4NH_2 + H_2O$	9.3×10^{-10}	9.03
K_2	$H_2NC_6H_4C_6H_4NH_3^+ + H_2O$	5.6×10^{-11}	10.25
Calcium hydroxide K_2	$Ca(OH)_2$	4.0×10^{-2}	1.40
Diethylamine	$(C_2H_5)_2NH + H_2O$	9.6×10^{-4}	3.02
Dimethylamine	$(CH_3)_2NH + H_2O$	1.1×10^{-3}	2.97
Diphenylamine	$(C_6H_5)_2NH + H_2O$	7.1×10^{-14}	13.15
Ethanolamine	$H_2NCH_2CH_2OH + H_2O$	1.8×10^{-5}	4.75
Ethylamine	$CH_3CH_2NH_2 + H_2O$	4.7×10^{-4}	3.33
Ethylenediamine K_1	$H_2NCH_2{=}CH_2NH_2 + H_2O$	9.1×10^{-5}	4.04
K_2		1.5×10^{-7}	6.82

Table 37 (continued)

Name	Formula	K_b	pK_b
Glycine	$HOOCCH_2NH_2$	2.3×10^{-12}	11.64
Guanidine	$(H_2N)_2CNH + H_2O$	3.0×10^{-1}	0.52
Hydrazine	$N_2H_4 + H_2O$	9.8×10^{-7}	6.01
Hydroxylamine	$NH_2OH + H_2O$	9.6×10^{-9}	8.02
8-Hydroxyquinoline	$C_9H_7ON + H_2O$	1.0×10^{-9}	8.99
Lead hydroxide K_1	$Pb(OH)_2$	9.55×10^{-4}	3.02
K_2		3.0×10^{-8}	7.52
Lithium hydroxide	$LiOH$	6.8×10^{-1}	0.17
Methylamine	$CH_3NH_2 + H_2O$	5.25×10^{-3}	3.28
α-Naphthylamine	$C_{10}H_7NH_2 + H_2O$	8.4×10^{-11}	10.08
β-Naphthylamine	$C_{10}H_7NH_2 + H_2O$	1.3×10^{-10}	9.89
Phenylhydrazine	$C_6H_5NHNH_2 + H_2O$	1.6×10^{-9}	8.80
Pyridine	$C_5H_5N + H_2O$	1.5×10^{-9}	8.82
Quinoline	$C_9H_7N + H_2O$	6.3×10^{-10}	9.20
Semicarbazide	$H_2NCONHNH_2 + H_2O$	2.7×10^{-11}	10.57
Silver hydroxide	$AgOH$	5.0×10^{-3}	2.30
Thiourea	$CS(NH_2)_2 + H_2O$	1.35×10^{-13}	11.87
Trimethylamine	$(CH_3)_3N + H_2O$	8.1×10^{-5}	4.09
Urea	$CO(NH_2)_2 + H_2O$	1.5×10^{-14}	13.82
Urotropine (hexamethylene tetramine)	$(CH_2)_6N_4 + H_2O$	1.4×10^{-9}	8.87

Table 38

Dissociation Constants of Complex Ions

The subscripts of K denote the number of groups of a ligand of a central atom of a complex which is dissociated by one step, for example, for Fe^{3+} complexes with chloride ions:

$$K_1=\frac{[Fe^{3+}][Cl^-]}{[FeCl^{2+}]};\qquad K_2=\frac{[FeCl^{2+}][Cl^-]}{[FeCl_2^+]};$$

$$K_3=\frac{[FeCl_2^+][Cl^-]}{[FeCl_3]};\qquad K_4=\frac{[FeCl_3][Cl^-]}{[FeCl_4^-]}$$

Two or more subscripts are written for complete dissociation constants of complexes with the corresponding number of groups of a ligand, for example:

$$K_{1,2}=\frac{[Fe^{3+}][Cl^-]^2}{[FeCl_2^+]};\qquad K_{1,2,3}=\frac{[Fe^{3+}][Cl^-]^3}{[FeCl_3]};$$

$$K_{1,2,3,4}=\frac{[Fe^{3+}][Cl^-]^4}{[FeCl_4^-]}$$

Evidently, $K_{1,2} = K_1 \cdot K_2$; $K_{1,2,3} = K_1 \cdot K_2 \cdot K_3$, etc. The table gives their indices, and not the constants themselves, i.e., the logarithms of the constants taken with an inverse sign:

$$pK_1 = -\log K_1;\ pK_2 = -\log K_2;\ pK_{1,2} = -\log K_{1,2},\ \text{etc.}$$

The indices of only complete dissociation constants are given; however, it follows from the above that the indices of the constants of separate dissociation steps can easily be found by the differences:

$$pK_2 = pK_{1,2} - pK_1;\quad pK_3 = pK_{1,2,3} - pK_{1,2},\ \text{etc.}$$

All data are given at temperatures of 20-30 °C.

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
A. Complexes with Inorganic Ligands							
Complexes with ammonia (NH_3)							
Ag^+	3.32	7.24	—	—	—	—	0
Au^+	?	27	—	—	—	—	?
Au^{3+}	?	?	?	30	—	—	?
Cd^{2+}	2.51	4.47	5.77	6.56	6.26	4.56	0
Co^{2+}	1.99	3.50	4.43	5.07	5.13	4.39	0
Co^{3+}	7.3	14.0	20.1	25.7	30.8	35.21	2

Table 38 (continued)

Central ion	pK_1	p$K_{1,2}$	p$K_{1,2,3}$	p$K_{1,2,3,4}$	p$K_{1,2,3,4,5}$	p$K_{1,2,3,4,5,6}$	Ionic strength
Cu^+	5.93	10.86	—	—	—	—	2
Cu^{2+}	3.99	7.33	10.06	12.03	11.43	8.9	0
Fe^{2+}	1.4	2.2	?	3.7	—	—	0
Hg^{2+}	8.8	17.5	18.5	19.3	—	—	2
Mg^{2+}	0.23	0.08	−0.34	−1.04	−1.99	−3.29	2
Mn^{2+}	0.8	1.3	?	?	?	9 (?)	2
Ni^{2+}	2.67	4.79	6.40	7.47	8.10	8.01	0
Tl^+	−0.9	—	—	—	—	—	2
Tl^{3+}	?	?	?	17 (?)	—	—	?
Zn^{2+}	2.18	4.43	6.74	8.70	—	—	0
Bromide complexes (Br$^-$)							
Ag^+	4.38*	7.34	8.00	8.73	—	—	0
Au^+	?	12.46	—	—	—	—	?
Au^{3+}	?	?	?	31.5	—	—	?
Bi^{3+}	2.26	4.45	6.33*	7.84	9.42	9.52	2
Cd^{2+}	2.23	3.00*	2.83	2.93	—	—	0
Ce^{3+}	0.38	—	—	—	—	—	0
Co^{2+}	−2.30	—	—	—	—	—	?
Cu^+	?	5.92	—	—	—	—	0
Cu^{2+}	−0.03	?	—	—	—	—	0
Fe^{3+}	0.55	0.82	—	—	—	—	0
Hg^{2+}	9.05	17.33*	19.74	21.00	—	—	0.5
In^{3+}	1.20	1.78	2.48*	3.33	—	—	1
Ni^{2+}	−0.12	−3.24*	?	−8.12	—	—	?
Pb^{2+}	2.23	3.00*	2.83	2.93	—	—	0
Pd^{2+}	?	?	?	13.10	—	—	0
Pt^{2+}	?	?	?	20.5	—	—	0
Sn^{2+}	0.73	1.14*	1.35	—	—	—	3
$SnOH^+$	0.70*	—	—	—	—	—	3
Tl^+	0.95	1.01	0.6	−0.2	—	—	0
Tl^{3+}	9.7	16.6	21.2*	23.9	25.5	26.2	0
UO_2^{2+}	−0.20	?	—	—	—	—	0
Zn^{2+}	−0.8	−2.2*	−2.9	−2.5	—	—	0
Complexes with hydrazine (N_2H_4)							
Cd^{2+}	2.25	2.40	2.78	3.89	—	—	1
Ni^{2+}	2.76	5.20	7.35	9.20	10.75	11.99	0.5
Zn^{2+}	3.40	3.70	3.78	3.88	—	—	1
Complexes with hydroxylamine (NH_2OH)							
Zn^{2+}	0.40	1.01	—	—	—	—	1

* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
			Hydroxocomplexes (OH^-)				
Ag^+	2.30*	4.0	5.2	—	—	—	0
Al^{3+}	9.04	?	?	33.0	—	—	0
AsO^+	14.33*	18.73	20.60	21.2	—	—	?
Ba^{2+}	0.85	—	—	—	—	—	0
Be^{2+}	7.48	?	15.21	15.0	—	—	0
Bi^{3+}	12.4	15.8	?	35.2	—	—	0
Ca^{2+}	1.46	—	—	—	—	—	0
Cd^{2+}	4.17	8.33*	9.02	<8.6	—	—	?
Ce^{3+}	4.6	—	—	—	—	—	?
Ce^{4+}	13.28	27.06	—	—	—	—	2
Co^{2+}	4.4	4.6*	10.5	—	—	—	0
Cr^{3+}	10.1	17.8	—	29.9	—	—	0
Cu^{2+}	7.0	13.68*	17.0	18.5	—	—	?
Fe^{2+}	5.56	9.77*	9.67	8.56	—	—	0
Fe^{3+}	11.87	21.17	30.67*	—	—	—	0
Ga^{3+}	11.0	21.7	?	34.3	38.0	40.3	0
Hg_2^{2+}	9.0	—	—	—	—	—	0.5
Hg^{2+}	10.30	21.70*	21.20	—	—	—	0.5
In^{3+}	9.9	19.8	?	28.7	—	—	0
La^{3+}	3.30	?	?	—	—	—	?
Li^+	0.17*	—	—	—	—	—	0
Mg^{2+}	2.58	?	—	—	—	—	0
Mn^{2+}	3.90	?	8.3	—	—	—	0
Ni^{2+}	4.97	8.55*	11.33	—	—	—	0
Pb^{2+}	6.9	10.8*	13.3	—	—	—	1
Sb^{3+}	?	24.3	36.7*	38.3	—	—	0
Sn^{2+}	11.86	20.64*	25.13	—	—	—	0
Sn^{4+}	?	?	?	?	?	63.0	0
Sr^{2+}	0.82	—	—	—	—	—	0
Th^{4+}	10.0	21.2	32.0	?	8.7	38.7	0
Tl^+	0.82*	—	—	—	—	—	0
Tl^{3+}	12.86	25.37	—	—	—	—	0
U^{4+}	13.3	?	?	?	41.2	—	0
UO_2^{2+}	9.8	18.6*	?	32.40	—	—	0.1
V^{3+}	11.1	21.6	—	—	—	—	?
VO^{2+}	8.6	—	—	—	—	—	?
VO^{3+}	?	25.2	?	46.2	58.5	—	?
Zn^{2+}	4.40	11.3*	13.14	14.66	—	—	?
Zr^{4+}	14.32	28.26	41.91	55.27*	—	—	1

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Hypophosphite Complexes ($H_2PO_2^-$)							
Fe^{3+}	2.77	—	—	—	—	—	?
Iodate complexes (IO_3^-)							
Ag^+	0.63*	1.90	—	—	—	—	0
Ba^{2+}	1.1	—	—	—	—	—	0
Ca^{2+}	0.89	—	—	—	—	—	0
Cu^{2+}	0.82	—	—	—	—	—	0
Mg^{2+}	0.72	—	—	—	—	—	0
Sr^{2+}	0.98	—	—	—	—	—	0
Th^{IV}	2.88	4.79	7.15	—	—	—	0.5
Tl^+	0.50*	—	—	—	—	—	0
Iodide complexes (I^-)							
Ag^+	6.58*	11.74	13.68	13.10	—	—	0
Bi^{3+}	2.89	?	?	14.95	16.80	19.1	0
Cd^{2+}	2.28	3.92*	5.00	6.10	—	—	0
Cu^+	?	8.85	—	—	—	—	0
Fe^{3+}	1.88	?	?	—	—	—	0
Hg^{2+}	12.87	23.82*	27.60	29.83	—	—	0.5
In^{3+}	1.64	2.56	2.48*	—	—	—	0.7
Pb^{2+}	1.26	2.80*	3.42	3.92	—	—	1
Tl^+	1.41*	1.82	2.0	1.6	—	—	?
Tl^{3+}	11.41	20.88	27.60*	31.82	—	—	0
Zn^{2+}	−2.9	−1.6*	−1.7	−2.3	—	—	4.5
*Carbonate complexes*** (CO_3^{2-})							
Ca^{2+}	3.2*	—	—	—	—	—	0
Cu^{2+}	6.0*	10.0	—	—	—	—	0
Mg^{2+}	3.40*	—	—	—	—	—	0
UO_2^{2+}	?	14.6	18.3	—	—	—	0
Nitrate complexes (NO_3^-)							
Ag^+	−0.29*	—	—	—	—	—	0
Ba^{2+}	0.92	—	—	—	—	—	0
Bi^{3+}	1.26	—	—	—	—	—	0.1
Ca^{2+}	0.28	—	—	—	—	—	0
Cd^{2+}	0.40	—	—	—	—	—	0
Ce^{3+}	1.04	1.51	—	—	—	—	2
Fe^{3+}	1.0	—	—	—	—	—	0

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* Neutral molecules in solution.

** For $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$, pK_1 is equal to 1.26 and 1.16, respectively.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Hf^{IV}	0.92	1.51	1.89	2.08*	2.08	1.81	4
Hg_2^{2+}	0.08	−0.24*	—	—	—	—	0.5
Hg^{2+}	0.35	~0*	—	—	—	—	?
La^{3+}	−0.26	—	—	—	—	—	1
Pb^{2+}	1.18	—	—	—	—	—	0
Pu^{IV}	0.54	—	—	—	—	—	1
Sr^{2+}	0.82	—	—	—	—	—	0
Th^{IV}	0.78	1.11	1.00	0.74*	—	—	2
Tl^{+}	0.33*	—	—	—	—	—	0
Tl^{3+}	0.92	—	—	—	—	—	0.6
U^{IV}	0.36	0.47	0.42	0.18*	—	—	4
UO_2^{2+}	−1.4*	−1.4*	−0.5	—	—	—	1
Zr^{IV}	0.34	0.11	−0.26	−0.82*	~−1.5	~−1.7	4
Nitrite complexes (NO_2^-)							
Ag^{+}	1.88*	2.83	—	—	—	—	?
Cd^{2+}	1.80	3.01*	3.81	3.1	—	—	3
Cu^{2+}	1.26	1.56*	1.16	—	—	—	5
Hg^{2+}	?	?	?	13.54	—	—	?
Perchlorate complexes (ClO_4^-)							
Ce^{3+}	1.91	—	—	—	—	—	0
Fe^{3+}	1.15	—	—	—	—	—	0
Hg_2^{2+}	−0.05	—	—	—	—	—	?
Pyrophosphate complexes ($P_2O_7^{4-}$)							
Ba^{2+}	4.64	—	—	—	—	—	?
Ca^{2+}	5.00	—	—	—	—	—	?
Cd^{2+}	5.6	4.18	—	—	—	—	3.5
Ce^{3+}	17.15	—	—	—	—	—	0
Co^{2+}	4.0	—	—	—	—	—	?
Cu^{+}	?	26.72	—	—	—	—	?
Cu^{2+}	5.20	10.30	—	—	—	—	?
Fe^{3+}	?	5.55	—	—	—	—	?
K^{+}	2.3	—	—	—	—	—	0
Li^{+}	2.39	—	—	—	—	—	1
Mg^{2+}	5.70	—	—	—	—	—	0.02
Na^{+}	2.22	—	—	—	—	—	0
Ni^{2+}	5.82	7.19	—	—	—	—	0.1

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Pb^{2+}	11.24	16.5	—	—	—	—	0.1
Sn^{2+}	14	—	—	—	—	—	?
Sr^{2+}	4.66	—	—	-	—	—	?
Tl^{+}	1.69	1.9	—	—	—	—	2
Zn^{2+}	8.7	11.0	—	—	—	—	?
Pyrophosphate complexes ($HP_2O_7^{3-}$)							
Cu^{2+}	6.4	10.0	—	—	—	—	?
Li^{+}	1.03	—	—	—	—	—	1
Na^{+}	1.52	—	—	—	—	—	0
Pyrophosphate complexes ($H_2P_2O_7^{2-}$)							
Sn^{2+}	4.48*	6.08	—	—	—	—	2
$SnOH^{+}$	5.48	7.30	—	—	—	--	2
Rhodanide complexes (SCN^{-})							
Ag^{+}	4.75*	8.23	9.45	9.67	—	—	0
Au^{+}	?	25	—	—	—	—	?
Au^{3+}	?	?	?	42.00	42.00	42.04	0
Bi^{3+}	1.15	2.26	?	3.41	?	4.23	0
Cd^{2+}	1.74	2.33*	~2	~3	—	—	0.1
Co^{2+}	3.0	3.0*	2.3	2.2	—	—	?
Cr^{3+}	3.08	4.8	5.8*	6.1	5.4	3.8	0
Cu^{+}	?	12.11	9.90	10.05	9.59	9.27	0
Cu^{2+}	2.30	3.65*	5.19	6.52	—	—	0
Fe^{2+}	0.95	0.07*	—	—	—	—	?
Fe^{3+}	3.03	4.33	4.63*	4.53	4.23	3.23	0
Hg^{2+}	?	17.47*	19.15	19.77	—	—	?
In^{3+}	2.58	3.60	4.63*	—	--	—	2
Ni^{2+}	1.18	1.64*	1.81	—	—	—	1
Pb^{2+}	1.09	2.52*	?	0.85	?	—0.30	?
Th^{4+}	1.08	?	1.78	—	—	—	1
$TiOH^{3+}$	1.7	—	—	—	—	—	1
Tl^{+}	0.80*	0.65	0.2	0	—	—	0
U^{4+}	1.49	1.95	2.18	—	—	—	1
UO_2^{2+}	0.93	0.91*	1.35	—	—	—	0
Zn^{2+}	1.7	2.1*	2.2	3.7	—	—	0.1
$ZnOH^{+}$	2.01*	?	2.66	—	—	—	1.7

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Selenate complexes (SeO_4^{2-})							
Cd^{2+}	2.27*	—	—	—	—	—	0
Zn^{2+}	2.19*	—	—	—	—	—	0
Selenite complexes (SeO_3^{2-})							
Cd^{2+}	?	5.15	—	—	—	—	1
Hg^{2+}	?	12.48	—	—	—	—	1
Sulphate complexes (SO_4^{2-})							
Al^{3+}	3.2	5.1	—	—	—	—	0
Ag^{+}	0.23	0.28	—	—	—	—	3
Ba^{2+}	2.36*	—	—	—	—	—	0
Ca^{2+}	2.31*	—	—	—	—	—	0
Cd^{2+}	2.31*	?	?	—	—	—	0
Ce^{3+}	3.37	—	—	—	—	—	0
Ce^{4+}	3.3	—	—	—	—	—	2
Co^{2+}	2.47*	—	—	—	—	—	0
Co^{3+}	1.34	—	—	—	—	—	2.7
Cu^{2+}	2.36*	?	—	—	—	—	0
Fe^{2+}	2.30*	—	—	—	—	—	0
Fe^{3+}	4.18	7.4	—	—	—	—	0
Hf^{4+}	3.11	5.58*	—	—	—	—	2
Hg_2^{2+}	1.30*	2.40	—	—	—	—	0.5
Hg^{2+}	1.34	2.3	—	—	—	—	0.5
In^{3+}	1.85	2.60	3.00	—	—	—	1
K^{+}	0.96	—	—	—	—	—	0
La^{3+}	3.82	—	—	—	—	—	0
Li^{+}	0.64	—	—	—	—	—	0
Mg^{2+}	2.36*	—	—	—	—	—	0
Mn^{2+}	2.28*	—	—	—	—	—	0
Na^{+}	0.72	—	—	—	—	—	0
Ni^{2+}	2.34*	—	—	—	—	—	0
Pb^{2+}	3.7*	—	—	—	—	—	0
Pu^{3+}	1.0	1.62	—	—	—	—	2
Pu^{4+}	3.66	—	6.46	4.44	—	—	1
Th^{4+}	3.32	5.70*	—	—	—	—	2
TiO^{2+}	2.40*	—	—	—	—	—	?
Tl^{+}	1.37	—	—	—	—	—	0
U^{4+}	3.24	5.42*	—	—	—	—	2

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
UO_2^{2+}	2.72*	4.20	—	—	—	—	0
VO^{2+}	2.48*	—	—	—	—	—	0
Zn^{2+}	2.34*	—	—	—	—	—	0
Zr^{4+}	3.79	6.64*	7.77	—	—	—	2
			Sulphite complexes (SO_3^{2-})				
Ag^+	5.60	8.68	9.00	—	—	—	0
Cd^{2+}	?	4.19	—	—	—	—	1
Cu^+	7.85	8.70	9.36	—	—	—	1
Hg^{2+}	?	24.07	24.96	—	—	—	0
Tl^{3+}	?	?	?	34	—	—	?
			Thiosulphate complexes ($S_2O_3^{2-}$)				
Ag^+	8.82	13.46	14.15	—	—	—	0
Ba^{2+}	2.33*	—	—	—	—	—	0
Ca^{2+}	1.91*	—	—	—	—	—	0
Cd^{2+}	3.94*	6.48	8.2	?	—	—	0
Co^{2+}	2.05*	—	—	—	—	—	0
Cu^+	10.27	12.22	13.84	—	—	—	2
Cu^{2+}	?	12.29	—	—	—	—	?
Fe^{2+}	2.0*	?	?	<2	—	—	0
Fe^{3+}	2.10	—	—	—	—	—	0.5
Hg^{2+}	?	29.86	32.26	33.61	—	—	0
K^+	1.00	—	—	—	—	—	0
La^{3+}	0.8	—	—	—	—	—	1
Mg^{2+}	1.79*	—	—	—	—	—	0
Mn^{2+}	1.95*	—	—	—	—	—	0
Na^+	0.58	—	—	—	—	—	0
Ni^{2+}	2.06*	—	—	—	—	—	0
Pb^{2+}	2.7*	5.13	6.35	7.2	—	—	?
Sr^{2+}	2.04*	—	—	—	—	—	0
Tl^+	1.91	—	—	—	—	—	0
Tl^{3+}	?	?	?	41	—	—	?
Zn^{2+}	2.29*	4.59	?	<0.6	—	—	0
			Tetrametaphosphate complexes ($P_4O_{12}^{4-}$)				
Ba^{2+}	4.99	—	—	—	—	—	0
Ca^{2+}	5.42	—	—	—	—	—	0
La^{3+}	6.66	—	—	—	—	—	0
Mg^{2+}	5.17	—	—	—	—	—	0

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Mn^{2+}	5.74	—	—	—	—	—	0
Ni^{2+}	4.95	—	—	—	—	—	0
Sr^{2+}	5.15	—	—	—	—	—	0
Trimetaphosphate complexes ($P_3O_9^{3-}$)							
Ba^{2+}	3.35	—	—	—	—	—	0
Ca^{2+}	3.45	—	—	—	—	—	0
La^{3+}	5.70	—	—	—	—	—	0
Mg^{2+}	3.31	—	—	—	—	—	0
Mn^{2+}	3.57	—	—	—	—	—	0
Na^+	1.17	—	—	—	—	—	0
Ni^{2+}	3.22	—	—	—	—	—	0
Sr^{2+}	3.35	—	—	—	—	—	0
Phosphate complexes (PO_4^{3-})							
Ce^{3+}	18.53*	—	—	—	—	—	0
Phosphate complexes (HPO_4^{2-})							
Ca^{2+}	2.70*	—	—	—	—	—	0
Fe^{3+}	9.75	—	—	—	—	—	0
Mg^{2+}	2.50*	—	—	—	—	—	0
Pu^{IV}	12.9	23.7*	33.4	43.2	52.0	—	2
Phosphate complexes ($H_2PO_4^-$)							
Al^{3+}	~3	~5.3	~7.6*	—	—	—	0.1
Ca^{2+}	1.08	—	—	—	—	—	0
Cu^{2+}	?	1.49*	—	—	—	—	0
Fe^{3+}	3.5	?	?	9.15	—	—	?
UO_2^{2+}	3.00	5.43*	7.33	—	—	—	0
Phosphate complexes (H_3PO_4)							
Pu^{IV}	2.3	—	—	—	—	—	2
Th^{IV}	1.89	—	—	—	—	—	2
UO_2^{2+}	<1.8	3.9	5.3	—	—	—	0
Fluoride complexes (F^-)							
Ag^+	0.36*	—	—	—	—	—	0
Al^{3+}	7.10	11.98	15.83*	18.53	20.20	20.67	0
Ba^{2+}	<0.45	—	—	—	—	—	0

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Be^{2+}	5.89	10.83*	14.39*	16.38	—	—	?
Ca^{2+}	<1.04	—	—	—	—	—	0
Cd^{2+}	0.46	0.53*	—	—	—	—	1
Ce^{3+}	3.99	—	—	—	—	—	0
Cr^{3+}	5.20	8.54	11.02*	—	—	—	0
Cu^{2+}	1.23	—	—	—	—	—	0
Fe^{3+}	6.04	10.74	13.74*	15.74	16.10	~16.10	0
Ga^{3+}	4.5	8.3	11.0*	12.5	12.8	—	?
Hg^{2+}	1.56	—	—	—	—	—	0
In^{3+}	4.63	7.41	10.23*	—	—	—	0
La^{3+}	3.56	—	—	—	—	—	0
Mg^{2+}	1.82	—	—	—	—	—	0
Mn^{3+}	5.76	—	—	—	—	—	2
Pu^{3+}	7.94	—	—	—	—	—	0
Sc^{3+}	7.08	12.88	17.33*	20.81	—	—	0
Sn^{2+}	4.85	?	~10	—	—	—	0
Sn^{4+}	?	?	?	?	?	~25	?
Th^{4+}	7.65	13.46	17.97	—	—	—	0.5
Tl^{+}	0.10*	—	—	—	—	—	0
TiO^{2+}	5.4	9.8*	13.8	17.5	—	—	3
UO_2^{2+}	4.4	7.7*	10.3	11.7	—	—	0
VO^{2+}	3.3	5.5*	7.2	7.5	—	—	1
Y^{3+}	4.81	8.54	12.14*	—	—	—	0
Zn^{2+}	1.26	—	—	—	—	—	0
Zr^{4+}	9.80	17.37	23.45	—	—	—	0
Chlorate complexes (ClO_3^-)							
Ba^{2+}	0.7	—	—	—	—	—	0
Ag^{+}	0.22*	—	—	—	—	—	0
Th^{4+}	0.26	—	—	—	—	—	0.5
Tl^{+}	0.47*	—	—	—	—	—	0
Chloride complexes (Cl^-)							
Ag^{+}	3.04*	5.04	5.04	5.30	—	—	0
Au^{+}	?	9.42	—	—	—	—	0
Au^{3+}	?	?	?	21.30	—	—	0
Bi^{3+}	2.43	4.7	5.0*	5.6	6.1	6.42	1
Cd^{2+}	2.05	2.60*	2.4	2.9	—	—	0
Ce^{3+}	0.22	—	—	—	—	—	0
Cr^{3+}	0.60	—0.11	—	—	—	—	?
Cu^{+}	?	5.35	5.63	—	—	—	0

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Cu^{2+}	0.07	—0.57*	—2.1	—	—	—	0
Fe^{2+}	0.36	0.40*	—	—	—	—	2
Fe^{3+}	1.45	2.10	1.10*	—0.85	—	—	0
Ga^{3+}	—0.6	—2.3	—4.5*	—6.8	—	—	0
Hg^{2+}	6.74	13.22*	14.07	15.07	—	—	0.5
In^{3+}	1.0	1.5	1.55*	1.35	—	—	0
Ir^{3+}	?	?	?	?	?	14.00	0
La^{3+}	—0.15	—	—	—	—	—	1
Mn^{3+}	0.95	—	—	—	—	—	2
MoO^{2+}	—0.3	—0.8*	—2.69	—	—	—	0
Pb^{2+}	1.62	2.44*	2.04	1.0	—	—	0
Pd^{2+}	6.1	10.5*	12.9	15.5	13.4	11.3	0
Pt^{2+}	?	?	14.00	16.00	—	—	0
Pu^{3+}	1.17	—	—	—	—	—	0
Pu^{4+}	—0.25	—	—	—	—	—	1
PuO_2^{2+}	0.10	—0.35*	—	—	—	—	2
Sn^{2+}	1.51	2.24*	2.03	1.48	—	—	0
$SnOH^+$	1.04*	—	—	—	—	—	3
Th^{4+}	1.38	0.38	0.23	—0.51*	—	—	0
Tl^+	0.52*	0.09	—0.8	—	—	—	0
Tl^{3+}	8.14	13.60	15.78*	18.00	17.47	—	0
U^{4+}	0.85	—	—	—	—	—	0
UO_2^{2+}	—0.1	—0.92*	—2.62	—	—	—	0
VO^{2+}	0.04	—	—	—	—	—	0
Zn^{2+}	—0.5	—1.0*	0.0	—1.0	—	—	0
Zr^{4+}	0.9	1.3	1.5	1.2*	—	—	6.5
			Cyanate complexes (CNO^-)				
Ag^+	?	5.00	—	—	—	—	0
			Cyanide complexes (CN^-)				
Ag^+	?	19.85	20.55	19.42	—	—	0
Au^+	?	38.3	—	—	—	—	0
Au^{3+}	?	?	?	56	—	—	0
Cd^{2+}	5.18	9.60*	13.92	17.11	—	—	?
Co^{2+}	?	—	?	?	?	19.09	5
Co^{3+}	?	—	?	?	?	64	?
Cu^+	?	24.0	28.6	30.3	—	—	0
Fe^{2+}	?	?	?	?	15.7	24	0
Fe^{3+}	?	?	?	?	?	31	0

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	p$K_{1,2}$	p$K_{1,2,3}$	p$K_{1,2,3,4}$	p$K_{1,2,3,4,5}$	p$K_{1,2,3,4,5,6}$	Ionic strength
Hg^{2+}	18.0	34.70*	38.53	41.51	—	—	0
Ni^{2+}	?	?	?	31.0	30.3	—	0
Tl^{3+}	?	?	?	35	—	—	0
Zn^{2+}	?	?	17	19	—	—	?
B. Complexes with Organic Ligands							
Acetate complexes (CH_3COO^-)							
Ag^+	0.73*	0.64	—	—	—	—	0
Ba^{2+}	0.41	—	—	—	—	—	0
Ca^{2+}	0.77	—	—	—	—	—	0
Cd^{2+}	1.30	2.28*	2.42	2.00	—	—	3
Ce^{3+}	1.68	2.65	3.23*	—	—	—	1
Cu^{2+}	2.24	3.30*	—	—	—	—	0
Fe^{2+}	3.2	6.1*	8.3	—	—	—	0.1
Fe^{3+}	3.2	—	—	—	—	—	1
In^{3+}	3.50	5.95	7.90*	9.08	—	—	2
Mg^{2+}	0.82	—	—	—	—	—	0
Mn^{2+}	1.2	—	—	—	—	—	0
Ni^{2+}	1.12	1.81*	—	—	—	—	0
Pb^{2+}	2.52	4.0*	6.4	8.5	—	—	0
Sr^{2+}	0.44	—	—	—	—	—	0
Tl^+	−0.11*	—	—	—	—	—	0
Tl^{3+}	?	?	?	15.4	—	—	0.2
UO_2^{2+}	2.38	4.36*	6.34	—	—	—	1
Zn^{2+}	1.57	—	—	—	—	—	0
Oxalate complexes $(COO)_2^{2-}$							
Al^{3+}	7.3	13	16.3	—	—	—	0
Ba^{2+}	2.3*	—	—	—	—	—	0
Be^{2+}	~4*	~6.5	—	—	—	—	?
Ca^{2+}	~3*	—	—	—	—	—	0
Cd^{2+}	4.00*	5.77	—	—	—	—	0
Ce^{3+}	6.52	10.48	11.30	—	—	—	0
Co^{2+}	4.7*	6.7	9.7	—	—	—	0
Cu^{2+}	6.7*	10.3	—	—	—	—	0.3
Fe^{2+}	?	4.52	5.22	—	—	—	0.5
Fe^{3+}	9.4	16.2	20.2	—	—	—	0
Mg^{2+}	2.55*	4.38	—	—	—	—	0
Mn^{2+}	3.82*	5.25	—	—	—	—	0

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Mn^{3+}	9.98	16.57	19.42	—	—	—	2
Nd^{3+}	7.21	11.51	$>$13.5	—	—	—	0
Ni^{2+}	$>$5.3*	6.51	$\sim$14	—	—	—	0
Pb^{2+}	?	6.54	—	—	—	—	0
Sr^{2+}	2.54*	—	—	—	—	—	0
Tl^{+}	2.03	—	—	—	—	—	0
Yb^{3+}	7.30	11.89	$>$12.9	—	—	—	0
Zn^{2+}	5.00*	7.36	8.15	—	—	—	0
Complexes with 8-hydroxyquinoline $(C_9H_6NO)^-$							
Ba^{2+}	2.07	—	—	—	—	—	0
Ca^{2+}	3.27	—	—	—	—	—	0
Cd^{2+}	7.2	13.4*	—	—	—	—	0.01
Co^{2+}	9.1	17.2*	—	—	—	—	0.01
Cu^{2+}	12.2	23.4*	—	—	—	—	0.01
Fe^{2+}	8.0	15.0*	—	—	—	—	0.01
Fe^{3+}	12.3	23.6	33.9*	—	—	—	0.01
Mg^{2+}	4.74	—	—	—	—	—	0
Mn^{2+}	6.8	12.6*	—	—	—	—	0.01
Ni^{2+}	9.9	18.7*	—	—	—	—	0.01
Pb^{2+}	9.02	—	—	—	—	—	0
Sr^{2+}	2.56	—	—	—	—	—	0
Th^{4+}	10.45	20.40	29.85	38.80*	—	—	0
UO_2^{2+}	11.25	20.89*	—	—	—	—	0.3
Zn^{2+}	8.50	16.72*	—	—	—	—	0
Complexes with pyridine (C_5H_5N)							
Ag^{+}	1.97	4.35	—	—	—	—	0
Cd^{2+}	1.27	2.14	2.3	2.50	—	—	0.1
Co^{2+}	1.14	1.54	—	—	—	—	0.5
Cu^{+}	?	3.3	—	—	—	—	?
Cu^{2+}	2.52	4.38	5.69	6.54	—	—	0.5
Fe^{2+}	0.71	?	?	6.7	—	—	0.5
Hg^{2+}	5.1	10.0	10.4	—	—	—	0.5
Ni^{2+}	1.78	2.82	3.13	—	—	—	0.5
Zn^{2+}	1.41	1.11	1.61	1.93	—	—	0.1
Salicylate complexes $[C_6H_4(COO)O]^{2-}$							
Al^{3+}	14.11	—	—	—	—	—	0
$^{**}Ca^{2+}$	0.36*	—	—	—	—	—	0.16

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* Neutral molecules in solution.

** $CaHSal^{+} \rightleftarrows Ca^{2+} + HSal^{-}$.

Table 38 (*continued*)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Cu^{2+}	10.6*	18.45	—	—	—	—	0.1
Fe^{2+}	6.55*	11.25	—	—	—	—	0.1
Fe^{3+}	16.48	28.16	36.84	—	—	—	0.25
Ni^{2+}	6.95*	11.75	—	—	—	—	0.1
Th^{4+}	4.25	7.60*	10.05	11.60	—	—	0.1
UO_2^{2+}	4.91*	—	—	—	—	—	?
Sulphosalicylate complexes $[C_6H_3O(COO)(SO_3)]^{3-}$							
Al^{3+}	13.20*	22.83	28.89	—	—	—	0.1
Be^{2+}	11.71	20.81	—	—	—	—	0.1
Cu^{2+}	9.52	16.45	—	—	—	—	0.1
Fe^{2+}	5.90	9.90	—	—	—	—	0.1
Fe^{3+}	15.02*	25.76	32.60	—	—	—	0.1
Mn^{2+}	5.24	8.24	—	—	—	—	0.1
UO_2^{2+}	11.14	19.20	—	—	—	—	0.1
Tartrate complexes $[(CHOH)_2(COO)]_2^{2-}$							
Ba^{2+}	2.54*	—	—	—	—	—	0
Ca^{2+}	2.98*	9.01	—	—	—	—	0
Cu^{2+}	3.00*	5.11	5.76	6.20	—	—	1
Fe^{3+}	7.49	—	—	—	—	—	?
Mg^{2+}	1.36*	—	—	—	—	—	0.2
Pb^{2+}	3.78*	—	—	—	—	—	?
Sr^{2+}	1.59*	—	—	—	—	—	0.16
Zn^{2+}	2.68*	—	—	—	—	—	0.2
Complexes with phenanthroline $(C_{12}H_8N_2)$							
Ag^+	5.02	12.07	—	—	—	—	0.1
Ca^{2+}	0.5	—	—	—	—	—	0.5
Cd^{2+}	6.4	11.6	15.8	—	—	—	0.1
Co^{2+}	7.25	13.95	19.90	—	—	—	0.1
Cu^{2+}	9.25	16.00	21.35	—	—	—	0.1
Fe^{2+}	5.85	?	21.3	—	—	—	0
Fe^{3+}	6.5	11.4	23.5	—	—	—	0.1
Zn^{2+}	6.43	12.15	17.0	—	—	—	0.1
Citrate complexes $[(CH_2)_2C(OH)(COO)_3]^{3-}$							
Ba^{2+}	2.84	—	—	—	—	—	0.08
Be^{2+}	4.52	—	—	—	—	—	0.15
Ca^{2+}	4.85	—	—	—	—	—	0

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1	$pK_{1,2}$	$pK_{1,2,3}$	$pK_{1,2,3,4}$	$pK_{1,2,3,4,5}$	$pK_{1,2,3,4,5,6}$	Ionic strength
Cd^{2+}	5.36	—	—	—	—	—	0
Co^{2+}	4.83	—	—	—	—	—	0.06
Cu^{2+}	14.21	—	—	—	—	—	0
Fe^{2+}	3.08	—	—	—	—	—	1
Fe^{3+}	11.7*	—	—	—	—	—	0.1
Mg^{2+}	3.29	—	—	—	—	—	0.09
Mn^{2+}	3.67	—	—	—	—	—	0.15
Ni^{2+}	5.11	—	—	—	—	—	0.15
Pb^{2+}	6.50	—	—	—	—	—	0
Sr^{2+}	2.90	—	—	—	—	—	0.15
UO_2^{2+}	7.40	—	—	—	—	—	0.1
	Citrate complexes $[(CH_2)_2C(OH)(COOH)(COO)_2]^{2-}$						
Be^{2+}	2.22*	—	—	—	—	—	0.15
Ca^{2+}	3.29*	—	—	—	—	—	0
Fe^{2+}	2.12*	—	—	—	—	—	0
Fe^{3+}	6.3	—	—	—	—	—	1
Pb^{2+}	5.72*	—	—	—	—	—	0

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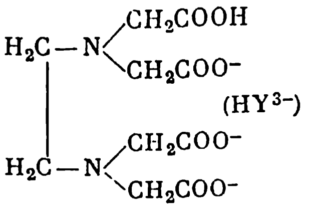
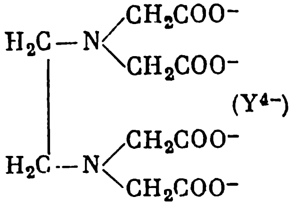
* Neutral molecules in solution.

Ethylenediaminetetraacetate complexes



(HY^{3-})



(Y^{4-})

(Ethylenediaminetetraacetic acid, H_4Y)
(Ionic strength = 0.1)

Central ion	pK_1HY^{3-}	pK_1Y^{4-}	Central ion	pK_1HY^{3-}	pK_1Y^{4-}
Ag^+	3.07	7.32	Ba^{2+}	2.07	7.78
Al^{3+}	8.4*	16.13	Ca^{2+}	3.51	10.57

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* Neutral molecules in solution.

Table 38 (continued)

Central ion	pK_1HY^{3-}	pK_1Y^{4-}	Central ion	pK_1HY^{3-}	pK_1Y^{4-}
Cd^{2+}	9.10	16.59	Na^{+}	—	1.66
Ce^{3+}	?	16.01	Ni^{2+}	11.56	18.62
Co^{2+}	9.15	16.21	Pb^{2+}	10.61	18.04
Co^{3+}	?	36	Pd^{3+}	?	18.5
Cr^{3+}	?	24.0	Sc^{3+}	?	23.1
Cu^{2+}	11.54	18.80	Sr^{2+}	2.30	8.63
Fe^{2+}	6.86	14.33	Th^{4+}	?	23.2*
Fe^{3+}	16.2*	25.10	Ti^{3+}	?	21.3
Ga^{3+}	11.39*	20.27	TiO^{2+}	?	17.3
Hg^{2+}	14.6	21.80	Tl^{3+}	?	5.8
In^{3+}	?	24.95	V^{2+}	?	12.70
La^{3+}	?	15.19	V^{3+}	?	25.9
Mg^{2+}	2.28	8.69	VO^{2+}	?	18.77
Mn^{2+}	6.9	14.04	Zn^{2+}	?	16.50

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* Neutral molecules in solution.

Table 39

Mobility of Selected Ions at 25 °C and Infinite Dilution

Equivalent conductivity (ohm$^{-1}\cdot$cm^2) of the electrolyte λ_{BA} is numerically equal to the sum of the mobilities of both ions: $\lambda_{BA} = \lambda_{B^+} + \lambda_{A^-}$

Cations	λ_{B^+}	Anions	λ_{A^-}
H^+	362	OH^-	205
K^+	76	1/4 $Fe(CN)_6^{4-}$	114
NH_4^+	76	1/3 $Fe(CN)_6^{3-}$	104
Tl^+	75	1/2 SO_4^{2-}	83
1/2 Pb^{2+}	73	1/2 CrO_4^{2-}	82
1/3 Fe^{3+}	68	Br^-	81
1/2 Ba^{2+}	66	1/3 PO_4^{3-}	80
Ag^+	64	I^-	80
1/2 Ca^{2+}	62	Cl^-	79
1/2 Sr^{2+}	62	NO_3^-	74
1/2 Cu^{2+}	57	1/2 $C_2O_4^{2-}$	74
1/2 Zn^{2+}	56	ClO_4^-	71
1/2 Mg^{2+}	55	1/2 CO_3^{2-}	70
1/2 Fe^{2+}	54	HCO_3^-	46
1/2 Ni^{2+}	52	$CH_3CO_2^-$	42
Na^+	52	IO_3^-	41
Li^+	39		

Table 40

Standard Oxidizing Potentials (E^0) Relative to the Potential of a Standard Hydrogen Electrode* at 25 °C

(↓ = saturated solution in the presence of a solid or liquid substance; ↑ = solution saturated with gas under a pressure of 1 atm)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Ag	Ag^{2+}	$+e$	Ag^+	+2.00
	Ag^+	$+e$	$Ag\downarrow$	+0.7994
	$AgBr\downarrow$	$+e$	$Ag\downarrow + Br^-$	+0.071
	$AgBrO_3\downarrow$	$+e$	$Ag\downarrow + BrO_3^-$	+0.55
	$AgC_2H_3O_2\downarrow$	$+e$	$Ag\downarrow + C_2H_3O_2^-$	+0.64
	$AgCN\downarrow$	$+e$	$Ag\downarrow + CN^-$	−0.04
	$Ag(CN)_2^-$	$+e$	$Ag\downarrow + 2CN^-$	−0.29
	$Ag(CN)_3^{2-}$	$+e$	$Ag\downarrow + 3CN^-$	−0.51
	$AgCNO\downarrow$	$+e$	$Ag\downarrow + CNO^-$	+0.41
	$Ag_2CO_3\downarrow$	$+2e$	$2Ag\downarrow + CO_3^{2-}$	+0.46
	$Ag_2C_2O_4\downarrow$	$+2e$	$2Ag\downarrow + C_2O_4^{2-}$	+0.472
	$AgCl\downarrow$	$+e$	$Ag\downarrow + Cl^-$	+0.224
	$Ag_2CrO_4\downarrow$	$+2e$	$2Ag\downarrow + CrO_4^{2-}$	+0.447
	$Ag_4Fe(CN)_6\downarrow$	$+4e$	$4Ag\downarrow + Fe(CN)_6^{4-}$	+0.194
	$AgI\downarrow$	$+e$	$Ag\downarrow + I^-$	−0.152
	$AgIO_3\downarrow$	$+e$	$Ag\downarrow + IO_3^-$	+0.35
	$Ag_2MoO_4\downarrow$	$+2e$	$2Ag\downarrow + MoO_4^{2-}$	+0.49
	$Ag(NH_3)_2^+$	$+e$	$Ag\downarrow + 2NH_3$	+0.373
	$AgNO_2\downarrow$	$+e$	$Ag\downarrow + NO_2^-$	+0.59
	$AgN_3\downarrow$	$+e$	$Ag\downarrow + N_3^-$	+0.293
	$2AgO\downarrow + H_2O$	$+2e$	$Ag_2O\downarrow + 2OH^-$	+0.60
	$AgO^+ + 2H^+$	$+e$	$Ag^{2+} + H_2O$	~+2.1
	$Ag_2O\downarrow + H_2O$	$+2e$	$2Ag\downarrow + 2OH^-$	+0.344
	$Ag_2O_3\downarrow + H_2O$	$+2e$	$2AgO\downarrow + 2OH^-$	+0.74
	$Ag_2S\downarrow$	$+2e$	$2Ag\downarrow + S^{2-}$	−0.71
	$AgSCN\downarrow$	$+e$	$Ag\downarrow + SCN^-$	+0.09
	$Ag(SO_3)_2^{3-}$	$+e$	$Ag\downarrow + 2SO_3^{2-}$	+0.43
	$Ag(S_2O_3)_2^{3-}$	$+e$	$Ag\downarrow + 2S_2O_3^{2-}$	+0.01
	$Ag_2SO_4\downarrow$	$+2e$	$2Ag\downarrow + SO_4^{2-}$	+0.653
	$Ag_2WO_4\downarrow$	$+2e$	$2Ag\downarrow + WO_4^{2-}$	+0.53
Al	Al^{3+}	$+3e$	$Al\downarrow$	−1.66
	$AlO_2^- + 2H_2O$	$+3e$	$Al\downarrow + 4OH^-$	−2.35
	$Al(OH)_3\downarrow$	$+3e$	$Al\downarrow + 3OH^-$	−2.31
	AlF_6^{3-}	$+3e$	$Al\downarrow + 6F^-$	−2.07

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*For the use of the table, see p. 476.

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
As	$As\downarrow + 3H^+$	$+3e$	$AsH_3\uparrow$	−0.60
	$As\downarrow + 3H_2O$	$+3e$	$AsH_3\uparrow + 3OH^-$	−1.37
	$HAsO_2 + 3H^+$	$+3e$	$As\downarrow + 2H_2O$	+0.247
	$H_3AsO_4 + 2H^+$	$+2e$	$HAsO_2 + 2H_2O$	+0.56
	$AsO_2^- + 2H_2O$	$+3e$	$As\downarrow + 4OH^-$	−0.68
	$AsO_4^{3-} + 2H_2O$	$+2e$	$AsO_2^- + 4OH^-$	−0.71
Au	Au^{3+}	$+2e$	Au^+	+1.41
	Au^{3+}	$+3e$	$Au\downarrow$	+1.50
	Au^+	$+e$	$Au\downarrow$	+1.68
	$AuBr_2^-$	$+e$	$Au\downarrow + 2Br^-$	+0.96
	$AuBr_4^-$	$+2e$	$AuBr_2^- + 2Br^-$	+0.82
	$AuBr_4^-$	$+3e$	$Au\downarrow + 4Br^-$	+0.87
	$Au(CN)_2^-$	$+e$	$Au\downarrow + 2CN^-$	−0.61
	$AuCl_2^-$	$+e$	$Au\downarrow + 2Cl^-$	+1.11
	$AuCl_4^-$	$+2e$	$AuCl_2^- + 2Cl^-$	+0.93
	$AuCl_4^-$	$+3e$	$Au\downarrow + 4Cl^-$	+0.99
	$H_2AuO_3^- + H_2O$	$+3e$	$Au\downarrow + 4OH^-$	+0.7
	$Au(SCN)_2^-$	$+e$	$Au\downarrow + 2SCN^-$	+0.69
	$Au(SCN)_4^-$	$+2e$	$Au(SCN)_2^- + 2SCN^-$	+0.64
	$Au(SCN)_4^-$	$+3e$	$Au\downarrow + 4SCN^-$	+0.66
B	$H_3BO_3 + 3H^+$	$+3e$	$B\downarrow + 3H_2O$	−0.87
	$H_2BO_3^- + H_2O$	$+3e$	$B\downarrow + 4OH^-$	−1.79
	BF_4^-	$+3e$	$B\downarrow + 4F^-$	−1.04
Ba	Ba^{2+}	$+2e$	$Ba\downarrow$	−2.90
Be	Be^{2+}	$+2e$	$Be\downarrow$	−1.85
	$Be_2O_3^{2-} + 3H_2O$	$+4e$	$2Be\downarrow + 6OH^-$	−2.62
Bi	$BiO^+ + 2H^+$	$+3e$	$Bi\downarrow + H_2O$	+0.32
	$Bi\downarrow + 3H^+$	$+3e$	$BiH_3\uparrow$	<-0.8
	$NaBiO_3\downarrow + 4H^+$	$+2e$	$BiO^+ + Na^+ + 2H_2O$	$>+1.8$
	$BiCl_4^-$	$+3e$	$Bi\downarrow + 4Cl^-$	+0.16
	$Bi_2O_4\downarrow + 4H^+$	$+2e$	$2BiO^+ + 2H_2O$	+1.59
	$Bi_2O_4\downarrow + H_2O$	$+2e$	$Bi_2O_3\downarrow + 2OH^-$	+0.56
	$Bi_2O_3\downarrow + 3H_2O$	$+6e$	$2Bi\downarrow + 6OH^-$	−0.46
	$BiOCl\downarrow + 2H^+$	$+3e$	$Bi\downarrow + H_2O + Cl^-$	+0.16
Br	Br_2	$+2e$	$2Br^-$	+1.087
	Br_3^-	$+2e$	$3Br^-$	+1.05
	$2HBrO + 2H^+$	$+2e$	$Br_2 + 2H_2O$	+1.6
	$2BrO^- + 2H_2O$	$+2e$	$Br_2 + 4OH^-$	+0.45

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	$E°$, V
Br	$HBrO + H^+$	$+2e$	$Br^- + H_2O$	+1.34
	$BrO^- + H_2O$	$+2e$	$Br^- + 2OH^-$	+0.76
	$BrO_3^- + 5H^+$	$+4e$	$HBrO + 2H_2O$	+1.45
	$BrO_3^- + 2H_2O$	$+4e$	$BrO^- + 4OH^-$	+0.54
	$2BrO_3^- + 12H^+$	$+10e$	$Br_2 + 6H_2O$	+1.52
	$2BrO_3^- + 6H_2O$	$+10e$	$Br_2 + 12OH^-$	+0.50
	$BrO_3^- + 6H^+$	$+6e$	$Br^- + 3H_2O$	+1.45
	$BrO_3^- + 3H_2O$	$+6e$	$Br^- + 6OH^-$	+0.61
C	$CH_3OH + 2H^+$	$+2e$	$CH_4\uparrow + H_2O$	+0.59
	$C_2H_5OH + 2H^+$	$+2e$	$C_2H_6\uparrow + H_2O$	+0.46
	$C_6H_4O_2 + 2H^+$ (quinone)	$+2e$	$C_6H_4(OH)_2$ (hydroquinone)	+0.6994
	$(CN)_2\uparrow + 2H^+$	$+2e$	$2HCN$	+0.37
	$2HCNO + 2H^+$	$+2e$	$2H_2O + (CN)_2\uparrow$	+0.33
	$HCNO + 2H^+$	$+2e$	$HCN + H_2O$	+0.35
	$CNO^- + H_2O$	$+2e$	$CN^- + 2OH^-$	—0.97
	$HCHO + 2H^+$	$+2e$	CH_3OH	+0.19
	$CH_3CHO + 2H^+$	$+2e$	C_2H_5OH	+0.19
	$HCOOH + 2H^+$	$+2e$	$HCHO$	—0.01
	$CH_3COOH + 2H^+$	$+2e$	CH_3CHO	—0.12
	$HCOO^- + 2H_2O$	$+2e$	$HCHO + 3OH^-$	—1.07
	$CO_2\uparrow + 2H^+$	$+2e$	$CO\uparrow + H_2O$	—0.12
	$CO_2\uparrow + N_2 + {} + 6H^+$	$+6e$	$CO(NH_2)_2 + H_2O$ (urea)	+0.1
	$CO_2\uparrow + 2H^+$	$+2e$	$HCOOH$	—0.20
	$2CO_2\uparrow + 2H^+$	$+2e$	$H_2C_2O_4$	—0.49
Ca	Ca^{2+}	$+2e$	$Ca\downarrow$	—2.87
	$Ca(OH)_2\downarrow$	$+2e$	$Ca\downarrow + 2OH^-$	—3.03
Cd	Cd^{2+}	$+2e$	$Cd\downarrow$	—0.402
	$CdCO_3\downarrow$	$+2e$	$Cd\downarrow + CO_3^{2-}$	—0.74
	$Cd(CN)_4^{2-}$	$+2e$	$Cd\downarrow + 4CN^-$	—1.09
	$Cd(NH_3)_4^{2+}$	$+2e$	$Cd\downarrow + 4NH_3$	—0.61
	$Cd(OH)_2\downarrow$	$+2e$	$Cd\downarrow + 2OH^-$	—0.81
	$CdS\downarrow$	$+2e$	$Cd\downarrow + S^{2-}$	—1.17
Ce	Ce^{3+}	$+3e$	$Ce\downarrow$	—2.33
	$Ce(ClO_4)_6^{2-}$	$+e$	$Ce^{3+} + 6ClO_4^-$	+1.70
	$Ce(NO_3)_6^{2-}$	$+e$	$Ce^{3+} + 6NO_3^-$	+1.60
	$Ce(SO_4)_3^{2-}$	$+e$	$Ce^{3+} + 3SO_4^{2-}$	+1.44
Cl	$Cl_2\uparrow$	$+2e$	$2Cl^-$	+1.359
	$2HOCl + 2H^+$	$+2e$	$Cl_2\uparrow + H_2O$	+1.63

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Cl	$2ClO^- + 2H_2O$	$+2e$	$Cl_2\uparrow + 4OH^-$	+0.40
	$HClO + H^+$	$+2e$	$Cl^- + H_2O$	+1.50
	$ClO^- + H_2O$	$+2e$	$Cl^- + 2OH^-$	+0.88
	$HClO_2 + 2H^+$	$+2e$	$HClO + H_2O$	+1.64
	$2HClO_2 + 6H^+$	$+6e$	$Cl_2\uparrow + 4H_2O$	+1.63
	$HClO_2 + 3H^+$	$+4e$	$Cl^- + 2H_2O$	+1.56
	$ClO_2^- + H_2O$	$+2e$	$ClO^- + 2OH^-$	+0.66
	$ClO_2^- + 2H_2O$	$+4e$	$Cl^- + 4OH^-$	+0.77
	$ClO_3^- + 3H^+$	$+2e$	$HClO_2 + H_2O$	+1.21
	$ClO_3^- + H_2O$	$+2e$	$ClO_2^- + 2OH^-$	+0.33
	$ClO_3^- + 2H^+$	$+e$	$ClO_2\uparrow + H_2O$	+1.15
	$ClO_2\uparrow + H^+$	$+e$	$HClO_2$	+1.27
	$ClO_3^- + 6H^+$	$+6e$	$Cl^- + 3H_2O$	+1.45
	$2ClO_3^- + 12H^+$	$+10e$	$Cl_2\uparrow + 6H_2O$	+1.47
	$ClO_3^- + 3H_2O$	$+6e$	$Cl^- + 6OH^-$	+0.63
	$ClO_2\uparrow + 4H^+$	$+5e$	$Cl^- + 2H_2O$	+1.50
	$ClO_2\uparrow + 2H_2O$	$+5e$	$Cl^- + 4OH^-$	+0.85
	$ClO_4^- + 2H^+$	$+2e$	$ClO_3^- + H_2O$	+1.19
	$ClO_4^- + H_2O$	$+2e$	$ClO_3^- + 2OH^-$	+0.36
	$2ClO_4^- + 16H^+$	$+14e$	$Cl_2\uparrow + 8H_2O$	+1.39
	$ClO_4^- + 8H^+$	$+8e$	$Cl^- + 4H_2O$	+1.38
	$ClO_4^- + 4H_2O$	$+8e$	$Cl^- + 8OH^-$	+0.56
Co	Co^{3+}	$+e$	Co^{2+}	+1.84
	Co^{3+}	$+3e$	$Co\downarrow$	+0.33
	Co^{2+}	$+2e$	$Co\downarrow$	−0.28
	$CoCO_3\downarrow$	$+2e$	$Co\downarrow + CO_3^{2-}$	−0.64
	$Co(NH_3)_6^{3+}$	$+e$	$Co(NH_3)_6^{2+}$	+0.1
	$Co(NH_3)_6^{2+}$	$+2e$	$Co\downarrow + 6NH_3$	−0.42
	$Co(OH)_2\downarrow$	$+2e$	$Co\downarrow + 2OH^-$	−0.73
	$Co(OH)_3\downarrow$	$+e$	$Co(OH)_2\downarrow + OH^-$	+0.17
	$CoS\ \alpha\downarrow$	$+2e$	$Co\downarrow + S^{2-}$	−0.88
	$CoS\ \beta\downarrow$	$+2e$	$Co\downarrow + S^{2-}$	−1.01
Cr	Cr^{3+}	$+e$	Cr^{2+}	−0.41
	Cr^{3+}	$+3e$	$Cr\downarrow$	−0.74
	Cr^{2+}	$+2e$	$Cr\downarrow$	−0.91
	$Cr(OH)_3\downarrow$	$+3e$	$Cr\downarrow + 3OH^-$	−1.3
	$Cr(OH)_2\downarrow$	$+2e$	$Cr\downarrow + 2OH^-$	−1.4
	$CrO_2^- + 2H_2O$	$+3e$	$Cr\downarrow + 4OH^-$	−1.2
	$Cr_2O_7^{2-} + 14H^+$	$+6e$	$2Cr^{3+} + 7H_2O$	+1.33
	$CrO_4^{2-} + 4H_2O$	$+3e$	$Cr(OH)_3\downarrow + 5OH^-$	−0.13

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Cs	Cs^+	$+e$	$Cs\downarrow$	-2.914
Cu	Cu^{2+}	$+2e$	$Cu\downarrow$	$+0.337$
	Cu^+	$+e$	$Cu\downarrow$	$+0.521$
	Cu^{2+}	$+e$	Cu^+	$+0.153$
	$Cu^{2+} + Br^-$	$+e$	$CuBr\downarrow$	$+0.64$
	$Cu^{2+} + Cl^-$	$+e$	$CuCl\downarrow$	$+0.54$
	$Cu^{2+} + I^-$	$+e$	$CuI\downarrow$	$+0.86$
	$CuBr\downarrow$	$+e$	$Cu\downarrow + Br^-$	$+0.033$
	$Cu(CN)_2^-$	$+e$	$Cu\downarrow + 2CN^-$	-0.43
	$CuCl\downarrow$	$+e$	$Cu\downarrow + Cl^-$	$+0.137$
	$CuI\downarrow$	$+e$	$Cu\downarrow + I^-$	-0.185
	$Cu(NH_3)_4^{2+}$	$+e$	$Cu(NH_3)_2^+ + 2NH_3$	-0.01
	$Cu(NH_3)_2^+$	$+e$	$Cu\downarrow + 2NH_3$	-0.12
	$Cu(NH_3)_4^{2+}$	$+2e$	$Cu\downarrow + 4NH_3$	-0.07
	$2Cu(OH)_2\downarrow$	$+2e$	$Cu_2O\downarrow + 2OH^- + H_2O$	-0.08
	$Cu_2O\downarrow + H_2O$	$+2e$	$2Cu\downarrow + 2OH^-$	-0.36
	$Cu(OH)_2\downarrow$	$+2e$	$Cu\downarrow + 2OH^-$	-0.22
	$CuS\downarrow$	$+2e$	$Cu\downarrow + S^{2-}$	-0.70
	$Cu_2S\downarrow$	$+2e$	$2Cu\downarrow + S^{2-}$	-0.88
	$CuSCN\downarrow$	$+e$	$Cu\downarrow + SCN^-$	-0.27
F	$F_2\uparrow$	$+2e$	$2F^-$	$+2.87$
Fe	Fe^{3+}	$+e$	Fe^{2+}	$+0.771$
	Fe^{3+}	$+3e$	$Fe\downarrow$	-0.036
	Fe^{2+}	$+2e$	$Fe\downarrow$	-0.440
	$Fe(CN)_6^{3-}$	$+e$	$Fe(CN)_6^{4-}$	$+0.356$
	$FeCO_3\downarrow$	$+2e$	$Fe\downarrow + CO_3^{2-}$	-0.756
	$Fe(C_{12}H_8N_2)_3^{3+}$ (1,10-phenanthroline)	$+e$	$Fe(C_{12}H_8N_2)_3^{2+}$	$+1.06$
	$Fe(OH)_3\downarrow$	$+e$	$Fe(OH)_2\downarrow + OH^-$	-0.56
	$Fe(OH)_2\downarrow$	$+2e$	$Fe\downarrow + 2OH^-$	-0.877
	$FeO_4^{2-} + 8H^+$	$+3e$	$Fe^{3+} + 4H_2O$	$>+1.9$
	$Fe_3O_4\downarrow + 8H^+$	$+8e$	$3Fe\downarrow + 4H_2O$	-0.085
	$FeS\downarrow$	$+2e$	$Fe\downarrow + S^{2-}$	-0.95
Ga	Ga^{3+}	$+3e$	$Ga\downarrow$	-0.56
	$H_2GaO_3^- + H_2O$	$+3e$	$Ga\downarrow + 4OH^-$	-1.22
Ge	$Ge\downarrow + 4H^+$	$+4e$	$GeH_4\uparrow$	<-0.3
	Ge^{2+}	$+2e$	$Ge\downarrow$	0.0
	$GeO\downarrow + 2H^+$	$+2e$	$Ge\downarrow + H_2O$	-0.29

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Ge	$GeO_2\downarrow + 4H^+$	$+4e$	$Ge\downarrow + 2H_2O$	−0.15
	$H_2GeO_3 + 4H^+$	$+4e$	$Ge\downarrow + 3H_2O$	−0.13
	$GeO_2\downarrow + 2H^+$	$+2e$	$GeO\downarrow$ (brown) $+ H_2O$	−0.12
	$HGeO_3^- + 2H_2O$	$+4e$	$Ge\downarrow + 5OH^-$	−1.0
H	$2H^+$	$+2e$	$H_2\uparrow$	±0.0000
	$2H^+(10^{-7}M)$	$+2e$	$H_2\uparrow$	−0.414
	$H_2\uparrow$	$+2e$	$2H^-$	−2.25
	$2H_2O$	$+2e$	$H_2\uparrow + 2OH^-$	−0.828
	$H_2O_2 + 2H^+$	$+2e$	$2H_2O$	+1.77
	$HO_2^- + H_2O$	$+2e$	$3OH^-$	+0.88
Hf	$HfO^{2+} + 2H^+$	$+4e$	$Hf\downarrow + H_2O$	−1.70
	$HfO_2\downarrow + 4H^+$	$+4e$	$Hf\downarrow + 2H_2O$	−1.57
	$HfO(OH)_2\downarrow + + H_2O$	$+4e$	$Hf\downarrow + 4OH^-$	−2.50
Hg	$2Hg^{2+}$	$+2e$	Hg_2^{2+}	+0.907
	Hg^{2+}	$+2e$	$Hg\downarrow$	+0.850
	Hg_2^{2+}	$+2e$	$Hg\downarrow$	+0.792
	$Hg_2Br_2\downarrow$	$+2e$	$2Hg\downarrow + 2Br^-$	+0.1392
	$Hg(CN)_4^{2-}$	$+2e$	$Hg\downarrow + 4CN^-$	−0.37
	$Hg_2(CH_3COO)_2\downarrow$	$+2e$	$2Hg\downarrow + 2CH_3COO^-$	+0.510
	$Hg_2C_2O_4\downarrow$	$+2e$	$2Hg\downarrow + C_2O_4^{2-}$	+0.415
	$Hg_2Cl_2\downarrow$	$+2e$	$2Hg\downarrow + 2Cl^-$	+0.2680
	$Hg_2I_2\downarrow$	$+2e$	$2Hg\downarrow + 2I^-$	−0.040
	$Hg_2(IO_3)_2\downarrow$	$+2e$	$2Hg\downarrow + 2IO_3^-$	+0.394
	$HgO\downarrow$ (red) $+ H_2O$	$+2e$	$Hg\downarrow + 2OH^-$	+0.098
	$HgS\downarrow$ (black)	$+2e$	$Hg\downarrow + S^{2-}$	−0.67
	$HgS\downarrow$ (red)	$+2e$	$Hg\downarrow + S^{2-}$	−0.70
	$Hg_2SO_4\downarrow$	$+2e$	$Hg\downarrow + SO_4^{2-}$	+0.614
I	$I_2\downarrow$	$+2e$	$2I^-$	+0.536
	I_2	$+2e$	$2I^-$	+0.621
	I_3^-	$+2e$	$3I^-$	+0.545
	$2IBr$	$+2e$	$I_2\downarrow + 2Br^-$	+1.02
	$2IBr_2^-$	$+2e$	$I_2\downarrow + 4Br^-$	+0.87
	ICN	$+2e$	$I^- + CN^-$	+0.30
	$2ICN + 2H^+$	$+2e$	$I_2\downarrow + 2HCN$	+0.63
	$2ICl$	$+2e$	$I_2\downarrow + 2Cl^-$	+1.19
	$2ICl_2^-$	$+2e$	$I_2\downarrow + 4Cl$	+1.06
	$2ICl_3$	$+6e$	$I_2\downarrow + 6Cl^-$	+1.28
	$2HIO + 2H^+$	$+2e$	$I_2\downarrow + 2H_2O$	+1.45
	$2IO^- + H_2O$	$+2e$	$I_2\downarrow + 4OH^-$	+0.45

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
I	$HIO + H^+$	$+2e$	$I^- + H_2O$	$+0.99$
	$IO^- + H_2O$	$+2e$	$I^- + 2OH^-$	$+0.49$
	$IO_3^- + 5H^+$	$+4e$	$HIO + 2H_2O$	$+1.14$
	$IO_3^- + 2H_2O$	$+4e$	$IO^- + 4OH^-$	$+0.14$
	$2IO_3^- + 12H^+$	$+10e$	$I_2\downarrow + 6H_2O$	$+1.19$
	$2IO_3^- + 6H_2O$	$+10e$	$I_2\downarrow + 12OH^-$	$+0.21$
	$IO_3^- + 6H^+$	$+6e$	$I^- + 3H_2O$	$+1.08$
	$IO_3^- + 3H_2O$	$+6e$	$I^- + 6OH^-$	$+0.26$
	$H_5IO_6 + H^+$	$+2e$	$IO_3^- + 3H_2O$	$\sim+1.6$
	$H_3IO_6^{2-}$	$+2e$	$IO_3^- + 3OH^-$	$\sim+0.7$
	$H_5IO_6 + 7H^+$	$+8e$	$I^- + 6H_2O$	$\sim+1.24$
	$H_3IO_6^{2-} + 3H_2O$	$+8e$	$I^- + 9OH^-$	$\sim+0.37$
In	In^{3+}	$+3e$	$In\downarrow$	-0.33
	In^{3+}	$+2e$	In^+	-0.40
	$In(OH)_3\downarrow$	$+3e$	$In\downarrow + 3OH^-$	-1.0
Ir	Ir^{3+}	$+3e$	$Ir\downarrow$	$\sim+1.15$
	$IrCl_6^{3-}$	$+3e$	$Ir\downarrow + 6Cl^-$	$+0.77$
	$IrCl_6^{2-}$	$+e$	$IrCl_6^{3-}$	$+1.02$
	$IrCl_6^{2-}$	$+4e$	$Ir\downarrow + 6Cl^-$	$+0.83$
	$IrO_2\downarrow + 4H^+$	$+4e$	$Ir\downarrow + 2H_2O$	$+0.93$
	$IrO_2\downarrow + 2H_2O$	$+4e$	$Ir\downarrow + 4OH^-$	$+0.1$
	$Ir_2O_3\downarrow + 3H_2O$	$+6e$	$2Ir\downarrow + 6OH^-$	$+0.1$
K	K^+	$+e$	$K\downarrow$	-2.925
La	La^{3+}	$+3e$	$La\downarrow$	-2.52
	$La(OH)_3\downarrow$	$+3e$	$La\downarrow + 3OH^-$	-2.90
Li	Li^+	$+e$	$Li\downarrow$	-3.03
Mg	Mg^{2+}	$+2e$	$Mg\downarrow$	-2.37
	$Mg(OH)_2\downarrow$	$+2e$	$Mg\downarrow + 2OH^-$	-2.69
Mn	Mn^{3+}	$+e$	Mn^{2+}	$+1.51$
	Mn^{2+}	$+2e$	$Mn\downarrow$	-1.19
	$Mn(CN)_6^{3-}$	$+e$	$Mn(CN)_6^{4-}$	-0.244
	$MnCO_3\downarrow$	$+2e$	$Mn\downarrow + CO_3^{2-}$	-1.48
	$Mn(OH)_2\downarrow$	$+2e$	$Mn\downarrow + 2OH^-$	-1.18
	$Mn(OH)_3\downarrow$	$+e$	$Mn(OH)_2\downarrow + OH^-$	$+0.1$
	$MnO_2 + 4H^+$	$+2e$	$Mn^{2+} + 2H_2O$	$+1.23$

Table 40 (continued

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Mn	$MnO_4^{2-} + 4H^+$	$+2e$	$MnO_2\downarrow + 2H_2O$	+2.26
	$MnO_4^{2-} + 2H_2O$	$+2e$	$MnO_2\downarrow + 4OH^-$	+0.6
	MnO_4^-	$+e$	MnO_4^{2-}	+0.56
	$MnO_4^- + 4H^+$	$+3e$	$MnO_2 + 2H_2O$	+1.69
	$MnO_4^- + 2H_2O$	$+3e$	$MnO_2\downarrow + 4OH^-$	+0.60
	$MnO_4^- + 8H^+$	$+5e$	$Mn^{2+} + 4H_2O$	+1.51
Mo	Mo^{3+}	$+3e$	$Mo\downarrow$	—0.2
	$Mo(CN)_8^{3-}$	$+e$	$Mo(CN)_8^{4-}$	+0.73
	$MoO_2^+ + 4H^+$	$+2e$	$Mo^{3+} + 2H_2O$	~0.0
	MoO_2^{2+}	$+e$	MoO_2^+	+0.48
	$H_2MoO_4 + 6H^+$	$+6e$	$Mo\downarrow + 4H_2O$	0.0
	$MoO_4^{2-} + 4H_2O$	$+6e$	$Mo\downarrow + 8OH^-$	—1.05
N	$HN_3 + 11H^+$	$+8e$	$3NH_4^+$	+0.69
	$N_3^- + 7H_2O$	$+6e$	$N_2H_4 + NH_3 + 7OH^-$	—0.62
	$3N_2\uparrow + 2H^+$	$+2e$	$2HN_3$	—3.1
	$3N_2\uparrow$	$+2e$	$2N_3^-$	—3.4
	$N_2\uparrow + 2H_2O + 4H^+$	$+2e$	$(2NH_2OH)H^+$	—1.87
	$N_2\uparrow + 4H_2O$	$+2e$	$2NH_2OH + 2OH^-$	—3.04
	$N_2\uparrow + 5H^+$	$+4e$	$(N_2H_4)H^+$	—0.23
	$N_2\uparrow + 4H_2O$	$+4e$	$N_2H_4 + 4OH^-$	—1.16
	$N_2\uparrow + 8H^+$	$+6e$	$2NH_4^+$	+0.26
	$N_2\uparrow + 8H_2O$	$+6e$	$2NH_4OH + 6OH^-$	—0.74
	$(N_2H_4)H^+ + 3H^+$	$+2e$	$2NH_4^+$	+1.27
	$N_2H_4 + 4H_2O$	$+2e$	$2NH_4OH + 2OH^-$	+0.1
	$(NH_2OH)H^+ + 2H^+$	$+2e$	$NH_4^+ + H_2O$	+1.35
	$NH_2OH + 2H_2O$	$+2e$	$NH_4OH + 2OH^-$	+0.42
	$H_2N_2O_2 + 2H^+$	$+2e$	$N_2\uparrow + 2H_2O$	+2.65
	$H_2N_2O_2 + 6H^+$	$+4e$	$(2NH_2OH)H^+$	+0.50
	$2HNO_2 + 4H^+$	$+4e$	$H_2N_2O_2 + 2H_2O$	+0.83
	$HNO_2 + H^+$	$+e$	$NO\uparrow + H_2O$	+0.99
	$NO_2^- + H_2O$	$+e$	$NO\uparrow + 2OH^-$	—0.46
	$2HNO_2 + 4H^+$	$+4e$	$N_2O\uparrow + 3H_2O$	+1.29
	$2HNO_2 + 6H^+$	$+6e$	$N_2\uparrow + 4H_2O$	+1.44
	$2NO_2^- + 4H_2O$	$+6e$	$N_2\uparrow + 8OH^-$	+0.41
	$HNO_2 + 7H^+$	$+6e$	$NH_4^+ + 2H_2O$	+0.86
	$NO_2^- + 6H_2O$	$+6e$	$NH_4OH + 7OH^-$	—0.15
	$N_2O\uparrow + 2H^+$	$+2e$	$N_2\uparrow + H_2O$	+1.77
	$N_2O\uparrow + H_2O$	$+2e$	$N_2\uparrow + 2OH^-$	+0.94
	$2NO\uparrow + 4H^+$	$+4e$	$N_2\uparrow + 2H_2O$	+1.68
	$2NO\uparrow + 2H_2O$	$+4e$	$N_2\uparrow + 4OH^-$	+0.85

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
N	$N_2O_4\uparrow + 2H^+$	$+2e$	$2HNO_2$	+1.07
	$N_2O_4\uparrow$	$+2e$	$2NO_2^-$	+0.88
	$N_2O_4\uparrow + 8H^+$	$+8e$	$N_2\uparrow + 4H_2O$	+1.35
	$N_2O_4\uparrow + 4H_2O$	$+8e$	$N_2\uparrow + 8OH^-$	+0.53
	$NO_3^- + 3H^+$	$+2e$	$HNO_2 + H_2O$	+0.94
	$NO_3^- + H_2O$	$+2e$	$NO_2^- + 2OH^-$	+0.01
	$NO_3^- + 2H^+$	$+e$	$NO_2\uparrow + H_2O$	+0.80
	$NO_3^- + H_2O$	$+e$	$NO_2\uparrow + 2OH^-$	—0.86
	$NO_3^- + 4H^+$	$+3e$	$NO\uparrow + 2H_2O$	+0.96
	$NO_3^- + 2H_2O$	$+3e$	$NO\uparrow + 4OH^-$	—0.14
	$2NO_3^- + 12H^+$	$+10e$	$N_2\uparrow + 6H_2O$	+1.24
	$NO_3^- + 8H^+$	$+6e$	$(NH_2OH)H^+ + 2H_2O$	+0.73
	$2NO_3^- + 17H^+$	$+14e$	$(N_2H_4)H^+ + 6H_2O$	+0.84
	$NO_3^- + 10H^+$	$+8e$	$NH_4^+ + 3H_2O$	+0.87
	$NO_3^- + 7H_2O$	$+8e$	$NH_4OH + 9OH^-$	—0.12
Na	Na^+	$+e$	$Na\downarrow$	—2.713
Nb	Nb^{3+}	$+3e$	$Nb\downarrow$	—1.1
	$Nb_2O_5\downarrow + 10H^+$	$+10e$	$Nb\downarrow + 5H_2O$	—0.65
	$NbO^{3+} + 2H^+$	$+2e$	$Nb^{3+} + H_2O$	—0.34
	$NbO(SO_4)_2^- +$ $+ 2H^+$	$+2e$	$Nb^{3+} + H_2O +$ $+ 2SO_4^{2-}$	—0.1
	$NbO(SO_4)_2^- +$ $+ 2H^+$	$+5e$	$Nb\downarrow + H_2O + 2SO_4^{2-}$	—0.63
Ni	Ni^{2+}	$+2e$	$Ni\downarrow$	—0.23
	$Ni(CN)_4^{2-}$	$+e$	$Ni(CN)_3^{2-} + CN^-$	<—0.4
	$NiCO_3\downarrow$	$+2e$	$Ni\downarrow + CO_3^{2-}$	—0.45
	$Ni(OH)_2\downarrow$	$+2e$	$Ni\downarrow + 2OH^-$	—0.72
	$Ni(NH_3)_6^{2+}$	$+2e$	$Ni\downarrow + 6NH_3$	—0.49
	$NiO_2\downarrow + 4H^+$	$+2e$	$Ni^{2+} + 2H_2O$	+1.68
	$NiO_2\downarrow + 2H_2O$	$+2e$	$Ni(OH)_2\downarrow + 2OH^-$	+0.49
	$NiO_4^{2-} + 8H^+$	$+4e$	$Ni^{2+} + 4H_2O$	>+1.8
	$NiS\ \alpha\downarrow$	$+2e$	$Ni + S^{2-}$	+0.76
	$NiS\ \gamma\downarrow$	$+2e$	$Ni\downarrow + S^{2-}$	—0.99
O	$O_2\uparrow + 4H^+$	$+4e$	$2H_2O$	+1.229
	$O_2\uparrow + 4H^+(10^{-7}M)$	$+4e$	$2H_2O$	+0.815
	$O_2\uparrow + 2H_2O$	$+4e$	$4OH^-$	+0.401
	$O_2\uparrow + 2H^+$	$+2e$	H_2O_2	+0.682
	$O_2\uparrow + H_2O$	$+2e$	$HO_2^- + OH^-$	—0.076
	$H_2O_2 + 2H^+$	$+2e$	$2H_2O$	+1.77
	$HO_2^- + H_2O$	$+2e$	$3OH^-$	+0.88
	$O_3\uparrow + 2H^+$	$+2e$	$O_2\uparrow + H_2O$	+2.07
	$O_3\uparrow + H_2O$	$+2e$	$O_2\uparrow + 2OH^-$	+1.24

Table 40 (continued)

Symbol of element	Highest degree of oxidation	+*ne*	Lowest degree of oxidation	E^0, V
Os	Os^{2+}	$+2e$	$Os\downarrow$	+0.85
	$OsCl_6^{2-}$	$+e$	$OsCl_6^{3-}$	+0.85
	$OsCl_6^{3-}$	$+3e$	$Os\downarrow + 6Cl^-$	+0.71
	$OsCl_6^{3-}$	$+e$	$Os^{2+} + 6Cl^-$	+0.4
	$OsO_4\downarrow + 6Cl^- + + 8H^+$	$+4e$	$OsCl_6^{2-} + 4H_2O$	+1.0
	$OsO_4\downarrow + 8H^+$	$+8e$	$Os\downarrow + 4H_2O$	+0.85
	$HOsO_5^- + 4H_2O$	$+8e$	$Os\downarrow + 9OH^-$	+0.02
P	$P\downarrow + 3H^+$	$+3e$	$PH_3\uparrow$	+0.06
	$P\downarrow + 3H_2O$	$+3e$	$PH_3\uparrow + 3OH^-$	—0.89
	$H_3PO_2 + H^+$	$+e$	$P\downarrow + 2H_2O$	—0.51
	$H_2PO_2^-$	$+e$	$P\downarrow + 2OH^-$	—2.05
	$H_3PO_3 + 3H^+$	$+3e$	$P\downarrow + 3H_2O$	—0.50
	$H_3PO_3 + 2H^+$	$+2e$	$H_3PO_2 + H_2O$	—0.50
	$HPO_3^{2-} + 2H_2O$	$+2e$	$H_2PO_2^- + 3OH^-$	—1.57
	$H_4P_2O_6 + 2H^+$	$+2e$	$2H_3PO_3$	+0.38
	$H_3PO_4 + 5H^+$	$+5e$	$P\downarrow + 4H_2O$	—0.41
	$H_3PO_4 + 4H^+$	$+4e$	$H_3PO_2 + 2H_2O$	—0.39
	$2H_3PO_4 + 2H^+$	$+2e$	$H_4P_2O_6 + 2H_2O$	—0.94
	$H_3PO_4 + 2H^+$	$+2e$	$H_3PO_3 + H_2O$	—0.276
	$PO_4^{3-} + 2H_2O$	$+2e$	$HPO_3^{2-} + 3OH^-$	—1.12
Pb	Pb^{2+}	$+2e$	$Pb\downarrow$	—0.126
	Pb^{4+}	$+2e$	Pb^{2+}	+1.8
	Pb^{4+}	$+4e$	$Pb\downarrow$	+0.84
	$PbBr_2\downarrow$	$+2e$	$Pb\downarrow + 2Br^-$	—0.274
	$PbCO_3\downarrow$	$+2e$	$Pb\downarrow + CO_3^{2-}$	—0.506
	$PbCl_2\downarrow$	$+2e$	$Pb\downarrow + 2Cl^-$	—0.266
	$PbF_2\downarrow$	$+2e$	$Pb\downarrow + 2F^-$	—0.350
	$PbI_2\downarrow$	$+2e$	$Pb\downarrow + 2I^-$	—0.364
	$PbO\downarrow + H_2O$	$+2e$	$Pb\downarrow + 2OH^-$	—0.58
	$HPbO_2^- + H_2O$	$+2e$	$Pb\downarrow + 3OH^-$	—0.54
	$PbO_2\downarrow + H_2O$	$+2e$	$PbO\downarrow + 2OH^-$	+0.28
	$PbO_2\downarrow + 4H^+$	$+2e$	$Pb^{2+} + 2H_2O$	+1.455
	$PbO_2\downarrow + 4H^+ + + SO_4^{2-}$	$+2e$	$PbSO_4\downarrow + 2H_2O$	+1.68
	$PbO_3^{2-} + H_2O$	$+2e$	$PbO_2^{2-} + 2OH^-$	+0.2
	$PbS\downarrow$	$+2e$	$Pb\downarrow + S^{2-}$	—0.91
	$PbSO_4\downarrow$	$+2e$	$Pb\downarrow + SO_4^{2-}$	—0.356
Pd	Pd^{2+}	$+2e$	$Pd\downarrow$	+0.987
	$PdCl_4^{2-}$	$+2e$	$Pd\downarrow + 4Cl^-$	+0.623
	$PdCl_6^{2-}$	$+2e$	$PdCl_4^{2-} + 2Cl^-$	+1.29
	$PdCl_6^{2-}$	$+4e$	$Pd\downarrow + 6Cl^-$	+0.96
	$Pd(OH)_2\downarrow$	$+2e$	$Pd\downarrow + 2OH^-$	+0.07

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Pd	$Pd(OH)_4\downarrow$	$+2e$	$Pd(OH)_2\downarrow + 2OH^-$	$\sim +0.73$
Pt	Pt^{2+}	$+2e$	$Pt\downarrow$	$\sim +1.2$
	$PtCl_4^{2-}$	$+2e$	$Pt\downarrow + 4Cl^-$	$+0.73$
	$PtCl_6^{2-}$	$+2e$	$PtCl_4^{2-} + 2Cl^-$	$+0.720$
	$Pt(OH)_2\downarrow$	$+2e$	$Pt\downarrow + 2OH^-$	$+0.15$
	$Pt(OH)_2\downarrow + 2H^+$	$+2e$	$Pt\downarrow + 2H_2O$	$+0.98$
Pu	Pu^{3+}	$+3e$	$Pu\downarrow$	-2.03
	Pu^{4+}	$+e$	Pu^{3+}	$+0.970$
	PuO_2^{2+}	$+e$	PuO_2^+	$+0.916$
	$PuO_2^{2+} + 4H^+$	$+2e$	$Pu^{4+} + 2H_2O$	$+1.04$
	$Pu(OH)_3\downarrow$	$+3e$	$Pu\downarrow + 3OH^-$	-2.42
	$Pu(OH)_4\downarrow$	$+e$	$Pu(OH)_3\downarrow + OH^-$	-0.95
Ra	Ra^{2+}	$+2e$	$Ra\downarrow$	-2.92
Rb	Rb^+	$+e$	$Rb\downarrow$	-2.93
Re	$Re\downarrow$	$+e$	Re^-	-0.4
	Re^+	$+2e$	Re^-	-0.23
	Re^{3+}	$+3e$	$Re\downarrow$	$\sim +0.3$
	$ReO_2\downarrow + 4H^+$	$+4e$	$Re\downarrow + 2H_2O$	$+0.26$
	$ReO_3\downarrow + 2H^+$	$+2e$	$ReO_2\downarrow + H_2O$	$+0.4$
	$ReO_4^- + 8H^+$	$+7e$	$Re\downarrow + 4H_2O$	$+0.37$
	$ReO_4^- + 4H^+$	$+3e$	$ReO_2\downarrow + 2H_2O$	$+0.51$
	$ReO_4^- + 2H^+$	$+e$	$ReO_3\downarrow + 2H_2O$	$+0.77$
	$ReO_4^- + 4H_2O$	$+7e$	$Re\downarrow + 8OH^-$	-0.584
	$ReO_4^- + 2H_2O$	$+3e$	$ReO_2\downarrow + 4OH^-$	-0.595
Rh	Rh^{3+}	$+3e$	$Rh\downarrow$	$\sim +0.8$
	$RhCl_6^{3-}$	$+3e$	$Rh\downarrow + 6Cl^-$	$+0.44$
	$Rh_2O_3\downarrow + 6H^+$	$+6e$	$2Rh\downarrow + 3H_2O$	$+0.87$
	$RhO_2 + 4H^+ + 6Cl^-$	$+e$	$RhCl_6^{3-} + 2H_2O$	$> +1.4$
	$RhO^{2+} + 2H^+$	$+e$	$Rh^{3+} + H_2O$	$+1.40$
	$RhO_4^{2-} + 6H^+$	$+2e$	$RhO^{2+} + 3H_2O$	$+1.46$
Ru	Ru^{2+}	$+2e$	$Ru\downarrow$	$+0.45$
	$RuCl_3$	$+3e$	$Ru\downarrow + 3Cl^-$	$+0.68$
	$RuCl_5^-$	$+2e$	$Ru^{2+} + 5Cl^-$	$+0.3$
	$RuCl_5OH^{2-} + H^+$	$+e$	$RuCl_5^{2-} + H_2O$	$+1.3$
	RuO_4^-	$+e$	RuO_4^{2-}	$+0.59$
	$RuO_4\downarrow$	$+e$	RuO_4^-	$+1.00$

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
S	$S\downarrow$	$+2e$	S^{2-}	-0.48
	$S\downarrow + 2H^+$	$+2e$	$H_2S\uparrow$	$+0.14$
	$5S\downarrow$	$+2e$	S_5^{2-}	-0.34
	$(SCN)_2\uparrow$	$+2e$	$2SCN^-$	$+0.77$
	$S_4O_6^{2-}$	$+2e$	$2S_2O_3^{2-}$	$+0.09$
	$S_2O_3^{2-} + 6H^+$	$+4e$	$2S\uparrow + 3H_2O$	$+0.5$
	$2H_2SO_3 + 2H^+$	$+4e$	$S_2O_3^{2-} + 3H_2O$	$+0.40$
	$2SO_3^{2-} + 3H_2O$	$+4e$	$S_2O_3^{2-} + 6OH^-$	-0.58
	$2H_2SO_3 + H^+$	$+2e$	$HS_2O_4^- + 2H_2O$	-0.08
	$2SO_3^{2-} + 2H_2O$	$+2e$	$S_2O_4^{2-} + 4OH^-$	-1.12
	$SO_4^{2-} + 4H^+$	$+2e$	$H_2SO_3 + H_2O$	$+0.17$
	$SO_4^{2-} + H_2O$	$+2e$	$SO_3^{2-} + 2OH^-$	-0.93
	$2SO_4^{2-} + 10H^+$	$+8e$	$S_2O_3^{2-} + 5H_2O$	$+0.29$
	$2SO_4^{2-} + 5H_2O$	$+8e$	$S_2O_3^{2-} + 10OH^-$	-0.76
	$SO_4^{2-} + 8H^+$	$+6e$	$S\downarrow + 4H_2O$	$+0.36$
	$SO_4^{2-} + 4H_2O$	$+6e$	$S\downarrow + 8OH^-$	-0.75
	$SO_4^{2-} + 10H^+$	$+8e$	$H_2S + 4H_2O$	$+0.31$
	$SO_4^{2-} + 4H_2O$	$+8e$	$S^{2-} + 8OH^-$	-0.68
	$S_2O_8^{2-}$	$+2e$	$2SO_4^{2-}$	$+2.0$
Sb	$Sb\downarrow + 3H^+$	$+3e$	SbH_3	-0.51
	$SbO^+ + 2H^+$	$+3e$	$Sb\downarrow + H_2O$	$+0.212$
	$Sb_2O_3\downarrow + 6H^+$	$+6e$	$2Sb\downarrow + 3H_2O$	$+0.152$
	$SbO_2^- + 2H_2O$	$+3e$	$Sb\downarrow + 4OH^-$	-0.675
	$Sb_2O_4\downarrow + 4H^+$	$+2e$	$2SbO^+ + 2H_2O$	$+0.68$
	$Sb_2O_5\downarrow + 4H^+$	$+4e$	$Sb_2O_3\downarrow + 2H_2O$	$+0.69$
	$Sb_2O_5\downarrow + 6H^+$	$+4e$	$2SbO^+ + 3H_2O$	$+0.58$
	$SbO_3^- + H_2O$	$+2e$	$SbO_2^- + 2OH^-$	-0.43
Sc	Sc^{3+}	$+3e$	$Sc\downarrow$	-2.08
Se	$Se\downarrow + 2H^+$	$+2e$	$H_2Se\uparrow$	-0.40
	$H_2SeO_3 + 4H^+$	$+4e$	$Se\downarrow + 3H_2O$	$+0.74$
	$SeO_3^{2-} + 3H_2O$	$+4e$	$Se\downarrow + 6OH^-$	-0.366
	$SeO_4^{2-} + 4H^+$	$+2e$	$H_2SeO_3 + H_2O$	$+1.15$
	$SeO_4^{2-} + H_2O$	$+2e$	$SeO_3^{2-} + 2OH^-$	$+0.05$
Si	$Si\downarrow + 4H^+$	$+4e$	$SiH_4\uparrow$	$+0.10$
	$Si\downarrow + 4H_2O$	$+4e$	$SiH_4\uparrow + 4OH^-$	-0.73
	SiF_6^{2-}	$+4e$	$Si\downarrow + 6F^-$	-1.2
	$SiO_2\downarrow + 4H^+$	$+4e$	$Si\downarrow + 2H_2O$	-0.86
	H_2SiO_3(hydrous) $+ 4H^+$	$+4e$	$Si\downarrow + 3H_2O$	-0.79
	$SiO_3^{2-} + 3H_2O$	$+4e$	$Si\downarrow + 6OH^-$	-1.7

Table 40 (continued)

Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
Sn	Sn^{2+}	$+2e$	$Sn\downarrow$	−0.140
	Sn^{4+}	$+2e$	Sn^{2+}	+0.15
	Sn^{4+}	$+4e$	$Sn\downarrow$	+0.01
	$HSnO_2^- + H_2O$	$+2e$	$Sn\downarrow + 3OH^-$	−0.91
	$Sn(OH)_6^{2-}$	$+2e$	$HSnO_2^- + 3OH^- + H_2O$	−0.93
Sr	Sr^{2+}	$+2e$	$Sr\downarrow$	−2.89
Ta	$Ta_2O_5\downarrow + 10H^+$	$+10e$	$2Ta\downarrow + 5H_2O$	−0.81
Te	$Te\downarrow + 2H^+$	$+2e$	$H_2Te\uparrow$	−0.72
	$Te\downarrow$	$+2e$	Te^{2-}	−1.14
	$TeO_2\downarrow + 4H^+$	$+4e$	$Te\downarrow + 2H_2O$	+0.53
	$TeO_2H^+ + 3H^+$	$+4e$	$Te\downarrow + 2H_2O$	+0.56
	$TeO_3^{2-} + 3H_2O$	$+4e$	$Te\downarrow + 6OH^-$	−0.57
	$H_6TeO_6\downarrow + 2H^+$	$+2e$	$TeO_2\downarrow + 4H_2O$	+1.02
	$TeO_4^{2-} + H_2O$	$+2e$	$TeO_3^{2-} + 2OH^-$	>+0.4
Th	Th^{4-}	$+4e$	$Th\downarrow$	−1.90
	$Th(OH)_4\downarrow$	$+4e$	$Th\downarrow + 4OH^-$	−2.48
Ti	Ti^{2+}	$+2e$	$Ti\downarrow$	−1.63
	$TiO_2\downarrow + 4H^+$	$+4e$	$Ti\downarrow + 2H_2O$	−0.86
	$TiO^{2+} + 2H^+$	$+4e$	$Ti\downarrow + H_2O$	~−0.88
	$TiO^{2+} + 2H^+$	$+e$	$Ti^{3+} + H_2O$	~+0.1
	Ti^{3+}	$+e$	Ti^{2+}	−0.37
	TiF_6^{2-}	$+4e$	$Ti\downarrow + 6F^-$	−1.19
Tl	Tl^+	$+e$	$Tl\downarrow$	−0.336
	$TlBr\downarrow$	$+e$	$Tl\downarrow + Br^-$	−0.656
	$TlCl\downarrow$	$+e$	$Tl\downarrow + Cl^-$	−0.557
	$TlOH$	$+e$	$Tl\downarrow + OH^-$	−0.344
	Tl^{3+}	$+2e$	Tl^+	+1.28
	$Tl_2O_3\downarrow + 3H_2O$	$+4e$	$2Tl^+ + 6OH^-$	+0.02
U	U^{3+}	$+3e$	$U\downarrow$	−1.8
	U^{4+}	$+e$	U^{3+}	−0.64
	$U(OH)_3\downarrow$	$+3e$	$U\downarrow + 3OH^-$	−2.17
	$UO_2\downarrow + 2H_2O$	$+4e$	$U\downarrow + 4OH^-$	−2.39
	$UO_2^+ + 4H^+$	$+e$	$U^{4+} + 2H_2O$	+0.55
	UO_2^{2+}	$+2e$	$UO_2\downarrow$	+0.45
	$UO_2^{2+} + 4H^+$	$+2e$	$U^{4+} + 2H_2O$	+0.33

Table 40 (continued)

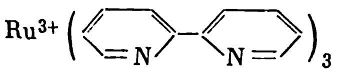
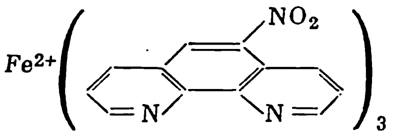
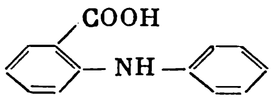
Symbol of element	Highest degree of oxidation	$+ne$	Lowest degree of oxidation	E^0, V
V	V^{2+}	$+2e$	$V\downarrow$	—1.18
	V^{3+}	$+e$	V^{2+}	—0.255
	$VO^{2+} + 2H^+$	$+e$	$V^{3+} + H_2O$	+0.337
	VO^{2+}	$+e$	VO^+	—0.044
	$VO_2^+ + 2H^+$	$+e$	$VO^{2+} + H_2O$	+0.9994
	$VO_2^+ + 4H^+$	$+2e$	$V^{3+} + 2H_2O$	+0.668
	$VO_2^+ + 4H^+$	$+3e$	$V^{2+} + 2H_2O$	+0.360
	$VO_2^+ + 4H^+$	$+5e$	$V\downarrow + 2H_2O$	—0.25
	$VO_4^{3-} + 6H^+$	$+2e$	$VO^+ + 3H_2O$	+1.26
	$H_2VO_4^- + 4H^+$	$+e$	$VO^{2+} + 3H_2O$	+1.31
W	$WO_2\downarrow + 4H^+$	$+4e$	$W\downarrow + 2H_2O$	—0.12
	$W(CN)_8^{3-}$	$+e$	$W(CN)_8^{4-}$	+0.457
	$W_2O_5\downarrow + 2H^+$	$+2e$	$2WO_2\downarrow + H_2O$	—0.04
	$WO_3\downarrow + 6H^+$	$+6e$	$W\downarrow + 3H_2O$	—0.09
	$2WO_3\downarrow + 2H^+$	$+2e$	$W_2O_5\downarrow + H_2O$	—0.03
	$WO_4^{2-} + 8H^+$	$+6e$	$W\downarrow + 4H_2O$	+0.05
	$WO_4^{2-} + 4H_2O$	$+6e$	$W\downarrow + 8OH^-$	—1.05
Y	Y^{3+}	$+3e$	$Y\downarrow$	—2.37
Zn	Zn^{2+}	$+2e$	$Zn\downarrow$	—0.7628
	$Zn(CN)_4^{2-}$	$+2e$	$Zn\downarrow + 4CN^-$	—1.26
	$Zn(NH_3)_4^{2+}$	$+2e$	$Zn\downarrow + 4NH_3$	—1.04
	$Zn(OH)_2\downarrow$	$+2e$	$Zn\downarrow + 2OH^-$	—1.245
	$ZnO_2^{2-} + 2H_2O$	$+2e$	$Zn\downarrow + 4OH^-$	—1.216
	$ZnS\downarrow$ (wurtzite)	$+2e$	$Zn\downarrow + S^{2-}$	—1.40
Zr	$ZrO^{2+} + 2H^+$	$+4e$	$Zr\downarrow + H_2O$	—1.57
	$ZrO_2\downarrow + 4H^+$	$+4e$	$Zr\downarrow + 2H_2O$	—1.43
	$H_2ZrO_3\downarrow + H_2O$	$+4e$	$Zr\downarrow + 4OH^-$	—2.36

Table 41

Chief Oxidation-Reduction Indicators

(in the order of their standard oxidation potentials)

A. Indicators not Sensitive to Changes in the pH and the Ionic Strength of a Solution

Indicator	Formula	Solution	$E°$, V	Colour of	
				oxidized form	reduced form
2, 2′-Dipyridyl (complex *with ruthenium)*		In diluted HCl	+1.33	Colourless	Yellow
Nitro-o-phenanthroline (nitroferroin), complex with Fe^{2+}		$0.025M$ solution in water	+1.25	Pale blue	Red $\lambda_{max} = 510$ nm
N-Phenyl-anthranylic acid		(a) 0.2% solution in water (b) 0.1% solution in 0.2% Na_2CO_3 solution	+1.08	Violet-red	Colourless

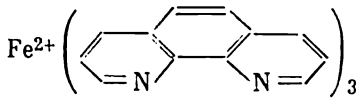
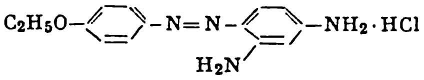
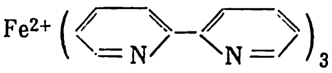
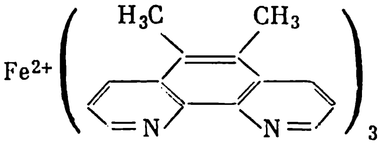
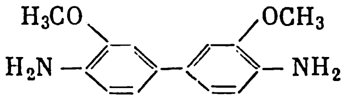
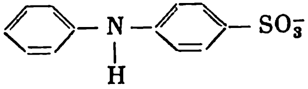
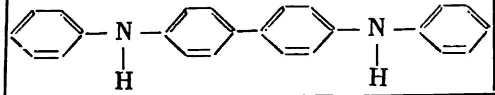
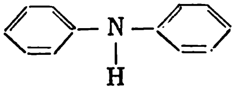
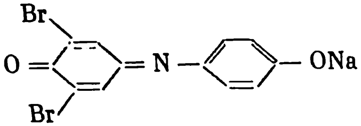
1,10-Phenanthroline (ferroin), complex with Fe^{2+}		0.025*M* solution; 1.624 g of phenanthroline hydrochloride and 0.695 g of $FeSO_4$ in 100 ml of water	+1.06	Pale blue	Red $\lambda_{max} = 510$ nm
p-Ethoxy chrysoidine		In water	+1.00	Red	Yellow
2, 2′-Dipyridyl (complex with Fe^{2+})		In diluted HCl	+0.97	Pale blue	Red
5,6-Dimethyl-1,10-phenanthroline (complex with Fe^{2+})		0.025*M* solution in water	+0.97	Yellow-green	Red
o-Dianisidine		In diluted HCl	+0.85	Red	Colourless

Table 41 (continued)

Indicator	Formula	Solution	$E°$, V	Colour of	
				oxidized form	reduced form
Sodium or barium diphenylamine sulphonate		0.05% solution in water	+0.84	Red-violet	Colourless
Diphenyl benzidine		1% solution in concentrated H_2SO_4	+0.76	Violet	Colourless
Diphenylamine		1% solution in concentrated H_2SO_4	+0.76	Violet	Colourless

B. Indicators Sensitive to a Change in the pH and the Ionic Strength of a Solution

Indicator	Formula	Solution	$E°$, V when the pH is equal to		Colour of	
			0	7	oxidized form	reduced form
2,6-Dibromobenzene indophenol (sodium salt)		0.02% solution in water	+0.64	+0.22	Blue	Colourless

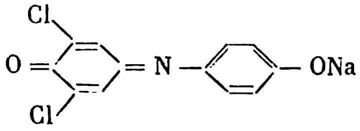
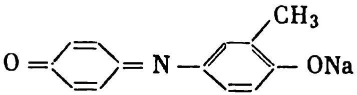
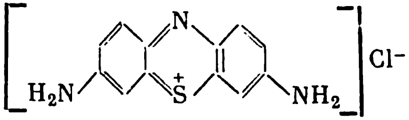
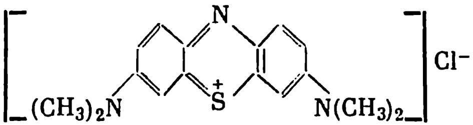
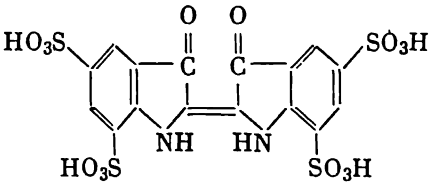
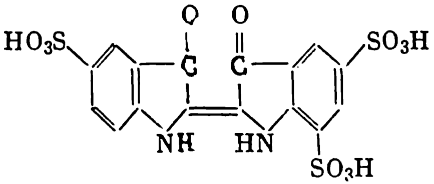
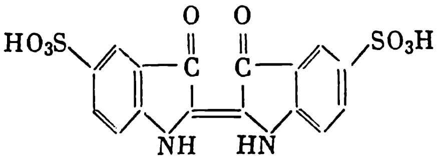
2,6-Dichlorophenol indophenol (sodium salt)		0.02% solution in water	+0.64	+0.22	Blue	Colourless
o-Cresol indophenol (sodium salt)		0.02% solution in water	+0.62	+0.19	Blue	Colourless
Thionine (diaminophenothiazine; Lauth's violet)		0.05% solution in 60% alcohol	+0.56	+0.06	Violet	Colourless
Methylene blue		0.05% solution in water	+0.53	+0.01	Blue	Colourless

Table 41 (continued)

Indicator	Formula	Solution	E°, V, when the pH is equal to		Colour of	
			0	7	oxidized form	reduced form
Indigo tetrasulphonic acid		0.05% solution in water	+0.37	—0.05	Blue	Colourless
Indigo trisulphonic acid		0.05% solution in water	+0.33	—0.08	Blue	Colourless
Indigo carmine (indigo disulphonic acid)		0.05% solution in water	+0.29	—0.13	Blue	Colourless

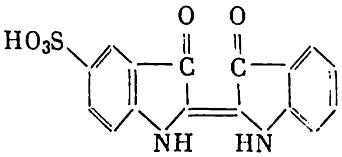
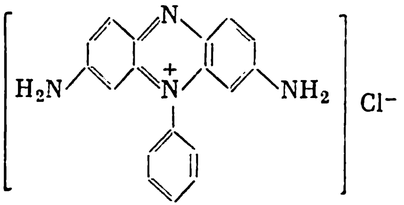
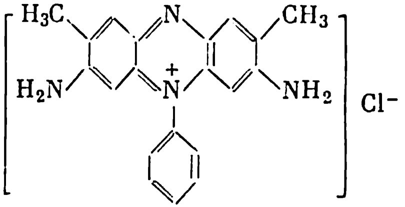
Indigo monosulphonic acid		0.05% solution in water	+0.26	—0.16	Blue	Colourless
Phenosafranine		0.05% solution in water	+0.28	—0.25	Red	Colourless
Safranine T		0.05% solution in water	+0.24	—0.29	Violet-red	Colourless
Neutral red	*See* Table 19, No. 43 (p. 189)	0.01% solution in 60% alcohol	+0.24	—0.33	Red	Colourless

Table 42

Spectral Wavelengths and Colours Corresponding to Them

Ranges of the wavelengths of the light being absorbed, nm	Colour of the radiation being absorbed	Supplementary colour (observed colour of solution)
400-450	Violet	Yellow-green
450-480	Blue	Yellow
480-490	Green-blue	Orange
490-500	Blue-green	Red
500-560	Green	Purple
560-575	Yellow-green	Violet
575-590	Yellow	Blue
590-625	Orange	Green-blue
625-750	Red	Blue-green

Table 43

Photometric Methods of Determining Various Ions

Ion being determined	Reagent	Solvent	pH or acidity	λ_{max}, nm	Molar coefficient of light absorption $\varepsilon \cdot 10^{-3}$
Al^{3+}	Aluminon	Water	4.5	525	24
	Arsenazo	Water	—	600	13.0
	Morin	95% alcohol	—	415	18
	Hydroxyquinoline	Chloroform	4.35-4.5	405	4.9
				260	80
	Stilbazo	Water	5.4	500	19.5
	Eriochrome cyanine R	Water	4-6	530	40
Ag^+	Dithizone	Carbon tetrachloride	H_2SO_4, 0.5*N*	462	30.5
	Diethyl dithiocarbamate	Carbon tetrachloride	2.6-5	340	5.4
	Rhodanine (*p*-dimethylaminobenzylidene rhodanine)	Water + ethanol, 4% by volume	1.3	595	23.2
As^{3+}	Diethyl dithiocarbamate	Carbon tetrachloride	3-6	340	3.6
AsO_4^{3-}	Ammonium molybdate + + hydrazine sulphate	Water	1-1.3	840	25
	Sodium molybdate	Butanol	HCl, diluted (1 : 3)	370	5.1
	Sodium molybdate + + sodium vanadate	Water	HCl, 1*N*	400	2.5

Table 43 (continued)

Ion being determined	Reagent	Solvent	pH or acidity	λ_{max}, nm	Molar coefficient of light absorption $\varepsilon \cdot 10^{-3}$
$AuBr_4^-$	Hydrobromic acid	Water	~1	380	4.8
$AuCl_4^-$	Rhodamine B	Benzene	HCl, 1*N*	565	97
	Methyl violet	Trichloroethylene	HCl, 1*N*	600	115
B^{3+}	Brilliant green + HF	Benzene	?	?	20
	Carminic acid	H_2SO_4, concentrated	—	585	?
	Curcumin	Ethanol, methanol or acetone	—	555	180
	Curcumin + oxalic acid	Ethanol	—	540	40
	Methylene blue + HF	Dichloroethane	?	645	14
	Quinalizarin	H_2SO_4, concentrated	—	620	?
Be^{2+}	Acetylacetone	Chloroform	7	295	31.6
	Aluminon	Water	7.6	535	2.2
	Beryllon	Water	12-13.2	600	4.0
	Eriochrome cyanine R	Water	9.8	512	?
Bi^{3+}	Dithizone	Carbon tetrachloride	6	490	80
	Diethyl dithiocarbamate	Carbon tetrachloride	7-10	400	6.3
	Potassium iodide	Isoamyl alcohol	H_2SO_4, 1*N*	450	6.5
	Potassium iodide	Water	H_2SO_4, 1*N*	337	34
	Complexone III	Water	4.5	264	9.4
	Hydroxyquinoline	Chloroform	4-5.2	395	11
	Hydrochloric acid, 6*N*	Water	—	327	14.9
	Thiourea	Water	HNO_3, 0.4-1.2*N*	470	8.8
				322	35

Br^-	Rosaniline	Benzyl alcohol	H_2SO_4, 18*N*	585	68
	Hypochlorite + H_2SO_4	Carbon tetrachloride	H_2SO_4, 2*N*	415	0.2
CN^-	Pyridine + benzidine	Water	—	520	69
	Pyridine + sulphanilic acid	Water	—	450	62
	Pyridine + barbituric acid	Water	—	584	124
Ca^{2+}	Azo-azoxy BN	Carbon tetrachloride	NaOH, 1*N*	485	20
	Arsenazo III	Water	6.5	655	10
	Phthalein complexone	Water	10-11	575	30
	Murexide	Water	11.3	506	11.3
Cd^{2+}	Dithizone	Carbon tetrachloride	4-12	520	88
	Diethyl dithiocarbamate	Carbon tetrachloride	9	440	0.21
	Cadion + acetone	Water	9.4	490	13
Ce^{3+}	Arsenazo III	Water	3.0	665	47
	Hydroxyquinoline	Chloroform	10	480	2
Ce^{4+}	Colour of ions themselves	Water	H_2SO_4, 1*N*	320	5.6
Cl^-	Hg^{2+} + diphenyl carbazone	Water	3.2	520	9.5
Cl_2	*o*-Tolidine	Water	1.6	438	26.5
Co^{2+}	Arsenazo	Water	—	600	25
	Dithizone	Carbon tetrachloride	6-8	542	59.2
	Diethyl dithiocarbamate	Chloroform	6.3	650	0.5
	α-Nitroso-β-naphthol	Chloroform	4-5.5	317	26.5
		Benzene	—	416	30

Table 43 (continued)

Ion being determined	Reagent	Solvent	pH or acidity	λ_{max}, nm	Molar coefficient of light absorption $\varepsilon \cdot 10^{-3}$
Co^{2+}	β-Nitroso-α-naphthol	Water	NH_3, 0.15*N*	550	7.5
		Toluene	~3	530	26
	Nitroso-R-salt	Water	5.0	420	23
	Hydroxyquinoline	Chloroform	6.8	420	7.8
	PAN	Chloroform	3-4	590	25
	Ammonium rhodanide	Isoamyl alcohol	3-5.3	312	6.8
		Isoamyl alcohol	—	620	1
		Cyclohexane	—	620	20
Cr^{3+}	Hydroxyquinoline	Chloroform	—	420	7.7
CrO_4^-	Colour of ions themselves	Water	Alkaline solution	370	4.9
$Cr_2O_7^{2-}$	Colour of ions themselves	Water	H_2SO_4, 0.9*N*	455	1.8
	Diphenyl carbazide	Water	1.2-2.6	540	34.6
	Chromotropic acid	Water	H_2SO_4, 0.5-5*N*	400	3.4
Cu^{2+}	Ammonia	Water	NH_3, 3*N*	620	0.12
	α-Benzoin oxime	Chloroform	11.3-12.3	440	2.8
	Dithizone	Carbon tetrachloride	HCl, 0.1*N*	545	45
		Carbon tetrachloride	6	445	22.7
	2,2′-Diquinoline	Isoamyl alcohol	5-6	540	5.5
	Diethyl dithiocarbamate	Chloroform	9-9.2	440	12
	8-Mercaptoquinoline	Toluene	HCl, 2.5*N*	432	8
	Hydroxyquinoline	Chloroform	2.7-14	410	5.2
	Pyridine + rhodanide	Chloroform	Weak acid solution	415	1.6

F^-	Alizarin S + Th^{IV}	Water	2	525	2
	SPADNS + Zr^{IV}	Water	HCl, diluted (7 : 3)	570	4.4
	Alizarin S + Zr^{IV}	Water	H_2SO_4, 0.6-1*M*	525	—
	Sulphosalicylic acid + + Fe^{3+}	Water	2.9	500	—
Fe^{2+}	Diethyl dithiocarbamate	Chloroform	0-10	515	2.7
	Dimethyl glyoxime	Water	Ammonia solution	550	10
	α,α'-Dipyridyl	Water	3-9	522	8.65
	α-Nitroso-β-naphthol	Ethylacetate	Weak alkaline solution	700	6.3
	1,10-Phenanthroline	Water	2-9	508	11.1
$Fe(CN)_6^{4-}$	Ferrous salt	Water	2-2.5	610	5
Fe^{3+}	Diethyl dithiocarbamate	Chloroform	0-10	515	2.7
	Cupferron	Chloroform	H_2SO_4 (1 : 9)	420	3.6
	α-Nitroso-β-naphthol	Chloroform	—	407	2.9
	Hydroxyquinoline	Chloroform	Weak acid solution	470	5.8
	Ammonium rhodanide	Water	0.3-1.2	480	6.3
	Salicylic acid	Water	2.6-2.8	520	1.6
	Sulphosalicylic acid	Water	8.2	420	5.5
	Ferron (7-iodo-8-quinolin-ol-5-sulphonic acid)	Water	2.7-3.1	610	3.6
	Hydrochloric acid	Water	HCl, 6.7*N*	342	2.9
$Fe(CN)_6^{3-}$	Ferric salt	Water	2-2.5	610	5
H^{IV}	Arsenazo III	Water	HCl, 9*N*	665	95
Hg^{2+}	Dithizone	Chloroform	5-6	492	70
	Diethyl dithiocarbamate	Carbon tetrachloride	3.7	340	1.0

Table 43 (continued)

Ion being determined	Reagent	Solvent	pH or acidity	λ_{max}, nm	Molar coefficient of light absorption $\varepsilon \cdot 10^{-3}$
I_2	Colour of the substance itself	Chloroform	—	510	0.46
		Chloroform	—	360	14.2
		Benzene	—	500	0.52
In^{3+}	Dithizone	Carbon tetrachloride	9	510	119
	Hydroxyquinoline	Chloroform	3.5	395	6.7
K^+	Dipicrylamine	Acetone (1 : 1)	10-11	500	0.8
Li^+	Thoron	Acetone (7 : 3)	13	486	6
Mg^{2+}	Hydroxyquinoline	Chloroform	11.2-11.3	380	5.6
	Titanium yellow	Water	>12	545	2.8
	Acid Chrome Black Special	Water	10	540	33
Mn^{3+}	Diethyl dithiocarbamate	Carbon tetrachloride	6-9	505	3.7
MnO_4^-	Colour of ions themselves	Water	<1	525	2.02
Mo^{5+}	Ammonium rhodanide	Diethyl ether	HCl, 0.8*N*	470	19.5
		Isoamyl alcohol	HCl, 1*N*	470	15.3
Mo^{VI}	Dithiol	Isoamyl acetate or petroleum ether	HCl, 4*N*	680	18

	8-Mercaptoquinoline	Toluene	HCl, 2.5N	420	7
	Hydroxyquinoline	Chloroform	—	369	8.2
NH_4^+	Sodium phenolate + hypochlorite	Water	NaOH, 0.8N	625	3.5
	Nessler's reagent	Water	13	400	6.2
NO_2^-	Sulphanilic acid + + α-naphthylamine	Water	2-2.5	520	40
NO_3^-	2,4-Phenol disulphonic acid	Water	—	410	9.4
	Brucine	Water	H_2SO_4, diluted (2 : 1)	410	1.5
Nb^V	PAR + H_2O_2	Water	5	540	32
	Hydrogen peroxide	Sulphuric acid, concentrated	—	365	0.86
	Pyrogallol	Water	H_2SO_4, diluted (1 : 40)	400	6.6
	Ammonium rhodanide + + $SnCl_2$.	Water + acetone (1 : 1)	HCl, 2-3N	383	38
		Diethyl ether	HCl, 4N	385	36.2
Ni^{2+}	Dimethyl glyoxime	Chloroform	Weak alkaline solution	375	3.5
	Ammonia	Water	NH_3, 1.5N	582	0.006
	Diethyl dithiocarbamate	Carbon tetrachloride	4-11	430	1.8
	Dithizone	Chloroform	NH_4OH, 0.3N	480	27
	Hydroxyquinoline	Chloroform	$\geqslant 6.7$	395	4.9
	Salicylaldoxine	Chloroform	—	400	6
	α-Furfuryl dioxime	Dichlorobenzene	7.5-8.3	438	17.6

Table 43 (continued)

Ion being determined	Reagent	Solvent	pH or acidity	λ_{max}, nm	Molar coefficient of light absorption $\varepsilon \cdot 10^{-3}$
Ni^{3+}	Dimethyl glyoxime + + oxidizer	Water	Ammonia solution	470	13
PO_4^{3-}	Ammonium molybdate	Water	HNO_3, 0.25N	360	4.8
	Ammonium molybdate + + $SnCl_2$	Water	HNO_3, 0.25N	735	18.5
	Ammonium molybdate + + ammonium vanadate	Water	HCl, 0.05N	315 400	20 2.5
Pb^{2+}	Arsenazo III	Water	4.5	655	10
	Dithizone	Carbon tetrachloride	8.5	520	68.8
	Diethyl dithiocarbamate	Carbon tetrachloride	4-11	340	9.3
	Sulpharsazene	Water	9.2	515	20
Pd^{2+}	Dithizone	Carbon tetrachloride	H_2SO_4, 0.5M	450	34.4
	Dimethyl glyoxime	Chloroform	HCl, 0.2-0.3N	383	1.6
	Potassium iodide	Water	HCl, up to 2N	408	9.4
	8-Mercaptoquinoline	Water	HCl, 6N	485	8.0
	α-Furfuryl dioxime	Chloroform	Strong acid solution	380	23.8
$PtCl_6^{2-}$	*p*-Nitrosomethylaniline	80% ethanol	2-5	525	67
	Potassium iodide	Water	1.6	495	12
	Tin dichloride	Water	HCl, diluted (1 : 9)	405	10

$ReCl_6^-$	α-Furfuryl dioxime + + $SnCl_2$	Water + 25% acetone	HCl, 0.8*N*	530	43
	8-Mercaptoquinoline	Chloroform	HCl, 8-11*N*	438	8.5
ReO_4^-	Methyl violet	Toluene	3.5-5	600	39.5
	Potassium rhodanide + + $SnCl_2$	Water	H_2SO_4, 4-7*N*	400	18
		Diethyl ether	H_2SO_4, 4-7*N*	432	37
S^{2-}	*p*-Aminodimethylaniline	Water	HCl, 0.55*N*	670	34
	The same reagents under conditions identical to those when CN^- is being determined; in addition:				
	Pyridine + copper sulphate	Chloroform	2.5-4	410 610	2.4 5
Sb^{3+} $SbCl_6^-$	Potassium iodide	Water	H_2SO_4, 2.4-3.8*N*	425	4
	Rhodamine V	Benzene	HCl, 6*N*	565	28
	Methyl violet	Toluene	HCl, 1.2*N*	600	50
	Safranine T	Benzene	HCl, 3.5*N*	518	37
Se^{IV}	3,3′-Diaminobenzidine	Water	HCl, 0.1*N*	348	14.3
		Toluene	6-7	420	9.9
SiO_3^{2-}	Ammonium molybdate	Water	1.6	352	7.1
	Ammonium molybdate + + Cl_2	Water	HCl, 2*N*	815	20
Sn^{2+}	Dithiol	Water	<1	530	5.8
	Hematoxylin	Water	2.5-4	580	43
	Diethyl dithiocarbamate	Carbon tetrachloride	4-5.8	415	2.4

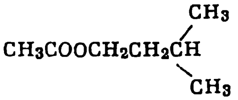
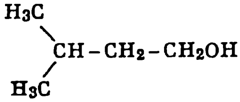
Table 43 (continued)

Ion being determined	Reagent	Solvent	pH or acidity	λ_{max}, nm	Molar coefficient of light absorption $\varepsilon \cdot 10^{-3}$
Sn^{2+}	Quercetin	Water	3-4	440	35.5
	Pyrocatechin violet	Water	2.3-4.5	610	60
	Phenylfluorone	Water	1	490	80
Ta^{V}	Dimethyl fluorone	Water	1	530	42
	Pyrogallol + oxalate	Water	HCl, 6N	365	5
TaF_6^-	Brilliant green	Benzene	0.6-2.0	600	68
	Methyl violet	Benzene	2.3	580	100
Te^{IV}	Diethyl dithiocarbamate	Carbon tetrachloride	4-8.8	428	3.2
	Bismuthol II	Water	6.5	400	14.7
		Chloroform	6.5	335	28
	Thiourea	Water	H_2SO_4, 1.8N	320	16
Th^{IV}	Arsenazo III	Water	HCl, 8N	665	127
	Carboxygallanilide	Water	4.5	413	25
	Morin	Water	2.0	410	42
	PAR	Water	6.4-6.7	500	38.9
	Thoron	Water	0.8	545	16.5
Ti^{4+}	Hydrogen peroxide	Water	H_2SO_4, 1.8N	410	0.72
	Sulphosalicylic acid	Water	3.2-4.9	370	15
	Thyrone	Water	4.3-9.6	410	16
	Chromotropic acid	Water	2.7-4.6	470	11.5

Tl^+	*Dithizone*	*Chloroform*	*NaOH, 0.8N*	505	33
Tl^{3+}	Diethyl dithiocarbamate	*Carbon tetrachloride*	4-11	426	1.3
	Methyl violet	Benzene	HCl, 0.5*N*	560	56
	Hydroxyquinoline	Chloroform	4-8	401	6.8
U^{IV}	Arsenazo III	Water	HCl, 4*N*	670	130
UO_2^{2+}	Arsenazo I	Water	4.2	555	22.8
	Arsenazo III	Water	2.0	665	53
	Dibenzoyl methane (1,3-diphenyl-1,3-propanedione)	Water	6.5-8.5	395	18
	Diethyl dithiocarbamate	Chloroform	6.5-7.2	380	4.0
	$K_4Fe(CN)_6$	Water	1-2	525	3.7
	Quinalizarin	Water	6.8-7.5	610	2.8
V^V	Wolframite + H_3PO_4	Isobutyl alcohol	HNO_3, 0.5*N*	400	2.2
	Diethyl dithiocarbamate	Carbon tetrachloride	4-5.9	400	3.8
	Hydroxyquinoline	Chloroform	4	550	3.3
	Hydrogen peroxide	Water	H_2SO_4, 1.5*N*	460	0.27
W^{VI}	Vanadicophosphoric acid	Water	H_3PO_4, diluted (1 : 100)	400	0.62
	Dithiol	Amyl acetate	0.5-2.0	640	20
	Rhodanide + $SnCl_2$	Water	HCl, 9*N*	400	11.5
		Diethyl ether	—	405	18.3
		60% acetone	—	398	17.6
	Hydroxyquinoline	Chloroform	—	357	3.3
Zn^{2+}	Dithizone	Carbon tetrachloride	8.3	535	94
	PAN	Carbon tetrachloride	5-6	560	28.7
Zr^{IV}	Alizarin S	Water	0.6-1.5	520	6.5
	Arsenazo I	Water	1.6	600	9.7
	Arsenazo III	Water	HCl, 9*N*	665	120
	Quercetin	30% ethanol	HCl, 0.5*N*	440	31.4
	Xylenol orange	Water	1.5	550	52
	SPADNS	Water	0.9-1.1	580	18.9
	Thoron	Water	2	570	3

Table 44

Properties of Selected Solvents

No.	Solvent	Formula	Molecular weight, *M*	Density at 20 °C, g/cm³	Refractive index
1	Acetic acid	CH_3COOH	60.054	1.049	1.372
2	Acetone	CH_3COCH_3	58.081	0.791	1.359
3	Amyl acetate (iso)	 $CH_3COOCH_2CH_2CH{<}^{CH_3}_{CH_3}$	130.190	0.856	1.400
4	Amyl alcohol (iso)	 ${}^{H_3C}_{H_3C}{>}CH-CH_2-CH_2OH$	88.151	0.806	1.406
5	Aniline	$C_6H_5NH_2$	93.130	1.022	1.586
6	Benzene	C_6H_6	78.144	0.8790	1.5014
7	Benzyl alcohol	$C_6H_5CH_2OH$	108.141	1.045	1.539
8	Butanol (iso)	$(CH_3)_2CHCH_2OH$	74.124	0.803	1.396
9	Butanol (normal)	C_4H_9OH	74.124	0.810	1.399
10	Butyl acetate (normal)	$CH_3COOC_4H_9$	116.162	0.882	1.395
11	Butylamine (normal)	$C_4H_9NH_2$	73.140	0.740	1.401
12	Butyl cellosolve (ethylene glycol mono-*n*-butyl ether)	$HO-CH_2-CH_2-O-C_4H_9$	118.178	0.902	1.417
13	Carbon disulphide	CS_2	76.143	1.263	1.627
14	Carbon tetrachloride	CCl_4	153.839	1.595	1.461
15	Chlorobenzene (mono)	C_6H_5Cl	112.563	1.107	1.525
16	Chloroform	$CHCl_3$	119.390	1.489	1.446
17	Cyclohexane	C_6H_{12}	84.163	0.779	1.426
18	Cyclohexanol	$C_6H_{11}OH$	100.162	0.494	1.465
19	Cyclohexanone	$C_6H_{10}O$	98.146	0.949	1.452
20	Decalin (decahydronaphthalene)	$C_{10}H_{18}$	138.255	0.890	1.475

Melting point, °C	Boiling point, °C	Vapour pressure, cm Hg	Surface tension at 20 °C, dynes/cm	Solubility in water, g/100 ml	Dielectric constant, (~20 °C)	Flash point, °C	No.
+16.6	118.1	1.5 (25 °C)	27.8	∞	9.5	40	1
−94.9	56.1	22.9 (25 °C)	23.7	∞	21.3	−16.7	2
−75	135.5	15.7 (20 °C)	—	0.25 (15 °C)	5.26	25	3
−134	128	0.2 (20 °C)	23.7	2.67 (25 °C)	15.8	42	4
−6.0	184.25	0.24 (50 °C)	42.9	3.66 (25 °C)	7.2	−71	5
+5.5	80.8	9.6 (25 °C)	28.9	0.175 (20 °C)	2.3	−8	6
−15.3	206	0.1 (60 °C)	38.3	3.66 (20 °C)	13.1	—	7
−108	108	1.8 (31 °C)	—	8.5 (20 °C)	18.8	34	8
−79.9	117.7	0.64 (25 °C)	24.6	7.9 (20 °C)	17.8	42	9
−77	125	18 (20 °C)	—	2.3 (20 °C)	5.0	22	10
−50.6	77.8	—	21.6	∞	5.4	—	11
−40	170.6	0.9 (20 °C)	—	50	—	60	12
−112.8	46.25	29.8 (20 °C)	33.6	0.18 (20 °C)	2.7	−20	13
−22.9	76.7	11.5 (25 °C)	26	0.08 (20 °C)	2.2	Does not ignite	14
−45	132.0	0.88 (20 °C)	33.2	0.049 (30 °C)	5.7	29	15
−63.5	61.2	19.9 (25 °C)	27.1	0.82 (20 °C)	5.1	Does not ignite	16
6.5	81	7.8 (25 °C)	—	0.01 (20 °C)	2.0	17	17
+24	161.5	1.0 (56 °C)	34.0	4.0 (20 °C)	10	68-72	18
—	155	0.85 (20 °C)	—	2.4 (30 °C)	—	40	19
−125	189-192	0.06 (20 °C)	—	practically insoluble	—	57-58	20

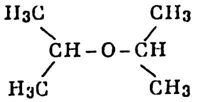
No.	Solvent	Formula	Molecular weight, M	Density at 20 °C, g/cm³	Refractive index
21	o-Dichlorobenzene	$C_6H_4Cl_2$	147.012	1.305	1.552
22	Dichloroethane (ethylene dichloride)	CH_2Cl-CH_2Cl	98.968	1.257	1.444
23	Diethyl ether (ethyl ether)	$C_2H_5OC_2H_5$	74.124	0.714	1.354
24	Diisopropyl ether (isopropyl ether)		102.178	0.715	1.368
25	1,4-Dioxane	$(CH_2)_4O_2$	88.108	1.033	1.422
26	Ethanol	C_2H_5OH	46.070	0.789	1.362
27	Ethanolamine	$H_2NCH_2CH_2OH$	61.086	1.018	1.454
28	Ethyl acetate	$CH_3COOC_2H_5$	88.108	0.901	1.372
29	Ethylene glycol	$HOCH_2CH_2OH$	62.070	1.114	1.431
30	Furfurol	$C_4H_3CHO_2$	96.087	1.160	1.526
31	Glycerin	$CH_2OHCHOHCH_2OH$	92.097	1.261	1.473
32	Hexane (normal)	C_6H_{14}	86.178	0.6603	1.3754
33	Methanol	CH_3OH	32.043	0.792	1.329
34	Methyl cellosolve (ethylene glycol monomethyl ether)	$HO-CH_2-CH_2-O-CH_3$	76.097	0.965	1.103
35	Methyl ethyl ketone	$CH_3COC_2H_5$	72.108	0.805	1.379
36	Methyl isobutyl ketone (hexone)	$(CH_3)_2CHCH_2COCH_3$	100.162	0.800	1.396
37	Nitrobenzene	$C_6H_5NO_2$	123.114	1.203	1.552
38	Octane (iso)	C_8H_{18}	114.232	0.708	1.401
39	Octane (normal)	C_8H_{18}	114.232	0.703	1.398
40	Propanol (iso)	C_3H_7OH	60.097	0.789	1.381
41	Propanol (normal)	C_3H_7OH	60.097	0.804	1.385
42	Pyridine	C_5H_5N	79.103	0.982	1.509
43	Sulphuric acid	H_2SO_4	98.082	1.834	1.429
44	Tetralin	$C_{10}H_{12}$	132.207	0.971	1.543
45	Toluene	$C_6H_5CH_3$	92.141	0.866	1.496
46	Turpentine	–	–	0.85-0.88	—1.47
47	Water	H_2O	18.016	0.997	1.333
48	Xylene (mixture of isomers)	C_8H_{10}	106.169	0.88	1.506

Table 44 (continued)

Melting point, °C	Boiling point, °C	Vapour pressure, cm Hg	Surface tension at 20 °C, dynes/cm	Solubility in water, g/100 ml	Dielectric constant, (~ 20 °C)	Flash point, °C	No.
−16.7	180.2	0.13 (25 °C)	—	0.014 (25 °C)	7.5	77	21
−35.3	83.5	7.7 (25 °C)	0.84	0.87 (20 °C)	10.5	12	22
−117.6	34.6	53.7 (25 °C)	16.5	6.95 (20 °C)	4.3	−40	23
<−60	68	15.8 (20 °C)	32	1.2 (25 °C)	—	−22	24
+11.7	101.1	2.7 (20 °C)	36.5	∞	3.0	5	25
−111.8	78.32	5.9 (25 °C)	21.9	∞	25.0	11	26
+10.5	172.2	—	—	∞	—	—	27
−83.6	77.15	7.3 (20 °C)	23.75	7.9 (20 °C)	6.2	4.4	28
−17.4	197.4	3.9 (120 °C)	47.7	∞	41.2	—	29
−39	162.1	2.5 (72 °C)	43.5	8.3 (20 °C)	41.9	94	30
+18.2	290	0.1 (125 °C)	64.5	∞	43	160	31
−94	68.8	15.1 (25 °C)	18.4	0.014 (16 °C)	1.9	−31	32
−94.9	64.65	12.4 (25 °C)	22.5	∞	32.3	6.5	33
—	124.5	6.2 (20 °C)	—	∞	17.2	36	34
−86	79.6	9.84 (25 °C)	24.6	27.3 (20 °C)	18.4	−7.2	35
−84	115.65	2.0 (25 °C)	—	2.3 (25 °C)	—	15.6	36
+5.7	210	0.75 (80 °C)	43.6	0.19 (20 °C)	35.5	90	37
−60	118	—	—	—	—	<−12	38
−57	125.0	1.1 (20 °C)	—	0.0015 (20 °C)	2.0	+17	39
−88.5	82.3	10.0 (39 °C)	21.7	∞	18.6	18.8	40
−127	97.2	1.45	23.6	∞	—	25	41
−38.2	115.1	1.54	36.6	∞	12.5	20	42
+10.5	(330)	<0.001 (25 °C)	(55)	∞	>84	Does not ignite	43
−35	207.3	0.03 (20 °C)	—	~0.001 (20 °C)	—	78	44
−95	110.8	2.8 (25 °C)	28.4	0.047 (20 °C)	2.4	5	45
—	153-180	0.45 (20 °C)	14.4	~0.2 (15 °C)	2.17	30-37	46
0.00	100.0	2.38 (25 °C)	72.75	—	80	Does not ignite	47
−25.3	136-145	1.0 (20 °C)	28	0.013 (25 °C)	2.4	20	48

Table 45

Extraction with Organic Solvents

A. Extraction of Various Elements in the Form of Dithizonates (Dr: dithizone ion)

Reagent—dithizone solution in chloroform or carbon tatrachloride; E—extracted by both organic solvents; N—cannot be extracted; N-E—weakly extracted

Element	Complex	Colour	Maximum light absorption λ, nm	Solubility in $CHCl_3$ or CCl_4	pH of extraction solution	Remarks
Ag^+	AgHDz	Yellow	460	E	Diluted mineral-acid solution	—
	Ag_2Dz	Violet-red	—	N	Alkaline solution	Insignificantly soluble in $CHCl_3$ (red solution)
Au^{3+}	$Au(HDz)_3$	Yellow	450	E	Diluted mineral-acid solution	Solutions are sensitive to light. Direct extraction titration and the photometric method are used
	Au_2Dz_3	Red-brown	—	E	Alkaline solution	Dissolves weakly in CCl_4. Solutions are sensitive to light. Direct extraction titration alone is used
Bi^{3+}	$Bi(HDz)_3$	Orange	490 and 275	E	>2 (CCl_4)	—
	Bi_2Dz_3	Orange-red	505	E	Alkaline solution	Reacts likewise in the presence of KCN
Cd^{2+}	$Cd(HDz)_2$	Red	520	E	Alkaline solution	Stable when being shaken with 1*N* NaOH solution

Co^{2+}	$Co(HDz)_2$	Violet-red	542	E	7-9 (CCl_4)	The dithizonate solution in an organic solvent is quite stable relative to diluted mineral acids
	CoDz(?)	Brown	—	E	Strong alkaline solution	Decomposition products may appear
Cu^+	CuHDz	Violet, the solution in CCl_4 is brown	—	E	Diluted mineral-acid solution (~0.1*N*)	—
	Cu_2Dz	Red-brown	—	E	Alkaline solution	Only insignificantly soluble in CCl_4
Cu^{2+}	$Cu(HDz)_2$	Violet-red	545-550	E	Diluted mineral-acid solution	The determination according to mixed colour should be made when $\lambda = 510$ nm or 625 nm
	CuDz	Yellow-brown	450	E	Alkaline solution	Can form also in a weak acid solution when copper ions are in the presence of excessive dithizone
Fe^{2+}	$Fe(HDz)_2$	Red	520	E	7-9 (CCl_4)	Fe^{III} does not form a complex, but it oxidizes dithizone in an alkaline medium, especially in the presence of cyanide
Hg_2^{2+}	$Hg_2(HDz)_2$	Orange	—	E	Diluted mineral-acid solution	—
	Hg_2Dz	Purple	485	N-E	Alkaline solution	—

Table 45 (continued)

Element	Complex	Colour	Maximum light absorption λ, nm	Solubility in $CHCl_3$ or CCl_4	pH of extraction solution	Remarks
Hg^{2+}	$Hg(HDz)_2$	Orange-yellow	485	E	Diluted mineral-acid solution	Can form in a weak alkaline solution with dithizone excess. Sensitive to light. The determination according to mixed colour should be made when λ = 500 nm or 610 nm
Hg^{2+}	HgDz	Red	520	E	Alkaline solution	Can form in a weak acid solution when there is a dithizone insufficiency
In^{3+}	$In(HDz)_3$	Red	510	E	5-6 (CCl_4); 8.3-9.6 ($CHCl_3$)	Reacts likewise in the presence of cyanide
Mn^{2+}	$Mn(HDz)_2$	Violet-brown	—	$CHCl_3$	~10	Solution is very unstable; brown flakes precipitate when CCl_4 substitutes $CHCl_3$
Ni^{2+}	$Ni(HDz)_2$	Brown-violet (when extracted from strong alkaline solutions, it is gray)	285, 480, 665	E	Weak alkaline solution	When CCl_4 is used, nickel dithizonate dissolved in it is decomposed by mineral acids with difficulty
Pb^{2+}	$Pb(HDz)_2$	Carmine red	520	E	8.5-11 (optimal in $CHCl_3$)	The presence of CN^- does not inhibit reaction

Pd^{2+}	$Pd(HDz)_2$	Brownish green; the solution in $CHCl_3$ is pale green	280, 640	E	—	Can be obtained by adding dithizone to a PdDz solution. Stable in respect of 6*N* NaOH and 6*N* H_2SO_4. The determination according to mixed colour is made when $\lambda = 620$ nm and 280 nm
	PdDz	Brownish red	—	N-E	Diluted mineral-acid solution	In organic solvents, it is soluble only partially, forming a dark-violet solution. Reaction occurs slowly
Pt^{2+}	$Pt(HDz)_2$	Brown-yellow	710, 490 and 260	CCl_4	HCl, 1.5-3*N*	Reaction is effected in the presence of $SnCl_2$; violet flakes occasionally appear. Platinous dithizonate is insoluble in $CHCl_3$. Platinum (IV) and other tetravalent and trivalent platinum metals do not react
Sn^{2+}	$Sn(HDz)_2$	Red	520	E	>4 (optimal 6-9) (CCl_4)	Unstable
Tl^{+}	TlHDz	Orange-red	505	E	11-14.5	Forms likewise in the presence of CN^-
Zn^{2+}	$Zn(HDz)_2$	Purple	535	E	Neutral or weak alkaline solution (optimal at pH = = 8.3 in a citrate buffer solution by the extraction with $CHCl_3$)	With dithizone excess, complete reaction occurs also in a weak acid medium. The presence of thiosulphate does not inhibit reaction

Table 45 (continued)

Action of Masking Agents during Extraction in the Form of Dithizonates

Extraction conditions	Elements reacting with dithizone
Alkaline solution containing cyanide	Pb^{2+}, Sn^{2+}, Tl^{+}, Bi^{3+}
Weak acid solution containing cyanide	Pd^{2+}, Hg^{2+}, Ag^{+}, Cu^{2+}
Diluted acid solution containing rhodanide	Hg^{2+}, Au^{3+}, Cu^{2+}
Diluted acid solution containing rhodanide and cyanide	Hg^{2+}, Cu^{2+}
Diluted acid solution containing bromide or iodide	Pb^{2+}, Au^{3+}, Cu^{2+}
Diluted acid solution containing ethylenediaminetetraacetate	Hg^{2+}, Ag^{+}
Weak acid solution (pH = 5) containing thiosulphate (dithizone is dissolved in CCl_4)	Pd^{2+}, Sn^{2+}, Zn^{2+} (Cd^{2+}, Co^{2+}, Ni^{2+})
Weak acid solution (pH = 4-5) containing thiosulphate and cyanide	Zn^{2+}, Sn^{2+}
Citrate and tartrate in an alkaline medium	Usually does not inhibit dithizonate extraction

B. Extraction of Various Elements in the Form of Diethyl Dithiocarbamates

Element	Optimal pH values in extraction	Extractant and extraction conditions
Ag^{+}	3	Ethyl acetate
	4-11	Carbon tetrachloride
As^{III}	4-5.6	ditto
Bi^{3+}	1-10	Chloroform, diethyl ether, ethyl acetate
	11-12	Carbon tetrachloride in the presence of ethylenediaminetetraacetate and KCN

Cd^{2+}	3	Ethyl acetate
	11-12	Carbon tetrachloride in the presence of KCN
Co^{2+}	6-8	Chloroform
Cr^{VI}	0-6	ditto
Cu^{2+}	1-3.5	ditto
	Alkaline solution	Ethyl acetate in the presence of ethylenediaminetetraacetate; the subsequent acid treatment allows separation from other elements being extracted under these conditions
Fe^{2+}	4-11	Carbon tetrachloride
Fe^{3+}	0-10	Chloroform
Ga^{3+}	3	Ethyl acetate (a reagent excess is required)
Hg^{2+}	3	Ethyl acetate
	11	Carbon tetrachloride in the presence of ethylenediaminetetraacetate
In^{3+}	3	Ethyl acetate
	9	Carbon tetrachloride in the presence of KCN
Mn^{2+}	6.5	Ethyl acetate (a reagent excess is required)
	7.5-8.0	Chloroform in the presence of citrate
Mo^{VI}	3	Ethyl acetate
Nb^{V}	4-5.5	Carbon tetrachloride
	0-10	Chloroform, ethyl acetate
Ni^{2+}	2.2	Chloroform
Os^{VI}	7-9 (extraction is slow and incomplete)	Carbon tetrachloride
Pb^{2+}	Strong acid solution	Diethyl ether, ethyl acetate
	11	Carbon tetrachloride in the presence of KCN
Pd^{2+}	11	Carbon tetrachloride in the presence of ethylenediaminetetraacetate

Table 45 (continued)

Element	Optimal pH values in extraction	Extractant and extraction conditions
Re^{VI}	HCl, concentrated	Ethyl acetate
Sb^{III}	4-9.5	Carbon tetrachloride
Se^{IV}	5-6	ditto
Sn^{IV}	5-6	ditto
Te^{IV}	3	Ethyl acetate
	5*N* H^+-3.3	Chloroform, benzene
	8.5-8.8	Carbon tetrachloride in the presence of ethylenediaminetetraacetate and KCN
Tl^+	3	Ethyl acetate (a reagent excess is required)
Tl^{3+}	11	Carbon tetrachloride in the presence of ethylenediaminetetraacetate and KCN
U^{VI}	6.5-8.5	Chloroform, amyl acetate, diethyl ether
V^V	3	Ethyl acetate
	4.5-5.0	Chloroform
	0.4-0.5	Amyl acetate in the presence of tartaric acid
W^{VI}	1-1.5	Ethyl acetate
Zn^{2+}	11	Carbon tetrachloride
	Weak alkaline solution	Diethyl ether, chloroform

Action of Masking Agents during Extraction in the Form of Diethyl Dithiocarbamates

Extraction conditions	Elements reacting with diethyl dithiocarbamate
In the presence of ethylenediaminetetraacetate at pH 11	Ag^+, Bi^{3+}, Cu^{2+}, Hg^{2+}, Pd^{2+}, Tl^{3+}
In the presence of KCN at pH 9	Bi^{2+}, In^{3+}, Mn^{2+}, Sb^{3+}, Te^{IV}, Tl^{3+}
Likewise at pH 11	Bi^{3+}, Cd^{2+}, Pb^{2+}, Tl^{3+}
In the presence of ethylenediaminetetraacetate and KCN at pH 9	Bi^{3+}, Sb^{3+}, Te^{IV}, Tl^{3+}
Likewise at pH 11	Bi^{3+}, Tl^{3+}

C. Extraction of Various Elements in the Form of Cupferronates

Element	Optimal conditions of extraction	Extractant
Al^{3+}	pH 2-5	Chloroform
Bi^{3+}	HCl, H_2SO_4	Toluene, methyl ethyl ketone
Cd^{2+}	Neutral solution	Boiling diethyl ether
Ce^{4+}	pH 2	Butyl acetate
Co^{2+}	CH_3COOH, diluted	Ethyl acetate or diethyl ether
Cu^{2+}	HCl, diluted (1 : 9)	Chloroform
Fe^{3+}	H_2SO_4 or HCl, diluted (1 : 9)	Chloroform, diethyl ether, ethyl acetate
Ge^{IV}	Weak acid solution	Methyl isobutyl ketone
Hg^{2+}	Neutral solution	Benzene, chloroform
In^{3+}	Diluted acid	ditto
Mn^{2+}	Neutral solution	Diethyl ether
Mo^{VI}	HCl, diluted (2 : 9)	Ethyl acetate, chloroform
Nb^{V}	Acid solution	Chloroform
Ni^{2+}	Neutral solution	Various organic solvents
Pa	1-4*N* acid	Benzene, diethyl ether, chloroform
Sb^{III}	H_2SO_4, diluted (1 : 9)	Chloroform
Sn^{2+}	1.5*N* acid	Benzene, chloroform
	Crystal violet + $TiCl_3$	4-Heptanone
Sn^{IV}	HCl, diluted (1 : 9)	Ethyl acetate
Th^{IV}	HCl, diluted (1 : 9)	Ethyl acetate, butyl acetate
	pH 0.3-0.8	Benzene + isoamyl alcohol
Ti^{IV}	HCl, diluted (1 : 9)	Chloroform, ethyl acetate
	Ammonium tartrate, pH 5	Isoamyl alcohol
U^{IV}	H_2SO_4, diluted (1 : 9)	Diethyl ether
V^{V}	HCl or H_2SO_4, diluted (1 : 9)	Ethyl acetate or ether
W^{VI}	HCl, diluted (1 : 9)	Ethyl acetate (incomplete extraction)
Zn^{2+}	Neutral solution	Diethyl ether (incomplete extraction)
Zr^{IV}	H_2SO_4, diluted (1 : 9)	Ethyl acetate
	pH 0.3-1.0	Benzene + isoamyl alcohol

Table 45 (continued)

D. Extraction of Various Elements in the Form of Hydroxyquinolates (1% hydroxyquinoline solution in chloroform)

Element	Optimal pH values in extraction	Extractant and extraction conditions
Al^{3+}	4.8-6.7; 8.2-11.5	—
Bi^{3+}	4.0-5.2	—
Ca^{2+}	13	Butyl cellosolve + chloroform
	11.5	Chloroform or, better, 0.2*M* butylamine solution in chloroform
Cd^{2+}	8	Incomplete extraction
Ce^{3+}	9.9-10.5	The presence of KCN is permissible
Co^{2+}	>6.8	—
Cu^{2+}	2.8-14	At high pH values, tartrate is added
Er^{3+}	>8.5	—
Fe^{3+}	1.9-12.5	At high pH values, tartrate is added
Ga^{3+}	3.0-6.2	—
In^{3+}	>3.0	—
Mg^{2+}	10-10.2	Butyl cellosolve + chloroform
	10.5-13.6	0.2*M* butylamine solution in chloroform
Mn^{2+}	12.5	In the presence of tartrate and hexacyanoferrate (II)
Mo^{VI}	1.6	Likewise in the presence of ethylenediaminetetraacetate
Nb^{V}	NH_4OH, 1*N*	Citrate medium
Nd^{3+}	>8.5	—
Ni^{2+}	4.5-9.5	—
Pa^{+}	$(NH_4)_2CO_3$, saturated solution	Incomplete extraction
Pb^{2+}	8.4-12.3	—

Pd^{2+}	HCl, diluted	—
Pu^{IV}	4-8	Amyl acetate
Ru^{III}	Acetate medium	—
Sc^{3+}	9.7-10.5	Benzene
Sn^{IV}	2.5-5.5	—
Sr^{2+}	11.3	1*M* hydroxyquinoline solution in chloroform
Th^{IV}	4.9	Chloroform or methyl isobutyl ketone
Ti^{IV}	3.8-5.0	In the presence of hydrogen peroxide
	8-9	In the presence of ethylenediaminetetraacetate
Tl^{3+}	6.5-7.0	85-89% is extracted
U^{VI}	4.7-8.0	—
	8.8	In the presence of ethylenediaminetetraacetate
V^{V}	3.3-4.5	—
	5.0	In the presence of an ethylenediaminetetraacetate complex with calcium ions
W^{VI}	2.4	In the presence of ethylenediaminetetraacetate
Zn^{2+}	4.6-13.4	Incomplete extraction
	Acetate buffer	—

Action of Masking Agents during Extraction in the Form of Hydroxyquinolates

Extraction conditions	Elements reacting with 8-hydroxyquinoline
In the presence of ethylenediaminetetraacetate, at pH 8 and higher, masking of Al^{3+}, Co^{2+}, Fe^{3+}, Mn^{2+} and Ni^{2+} occurs	
At pH 7.9-9.0	Ti
At pH 2.5-9.0	Cu

Table 45 (continued)

E. Extraction of Various Elements from Hydrochloric, Hydrobromic, Hydroiodic and Nitric Acids by an Equal Volume of Diethyl Ether

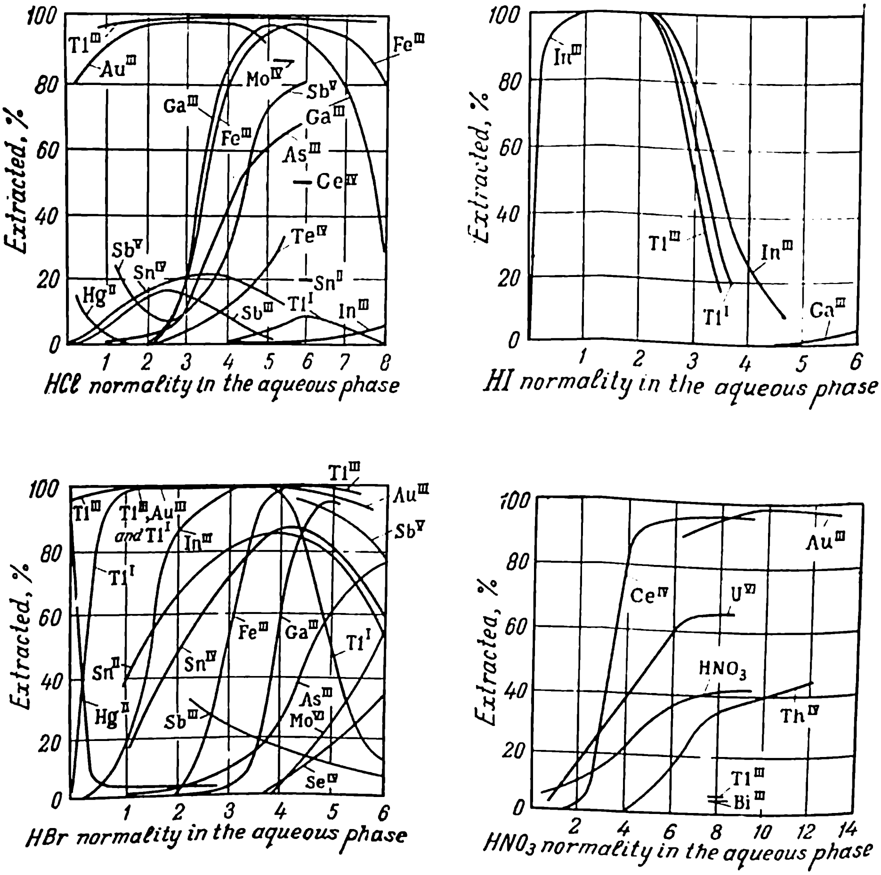


Table 46

Separation of Organic Compounds

A. Classification of Individual Compounds According to Their Behaviour under the Action of Some Reagents

A test of the examined compound is consecutively treated with the following reagents: (a) distilled water, (b) diethyl ether, (c) 1.2*N* hydrochloric acid, (d) 1.5*N* sodium bicarbonate solution, (e) 2.5*N* caustic soda solution, (f) concentrated sulphuric acid, and (g) 85% phosphoric acid.

These reagents are used to treat separate portions of the test in the given order. A test is considered to be soluble in one reagent or another if it dissolves upon shaking for two minutes at room temperature in a quantity which is 30 times greater in mass than the given reagent.

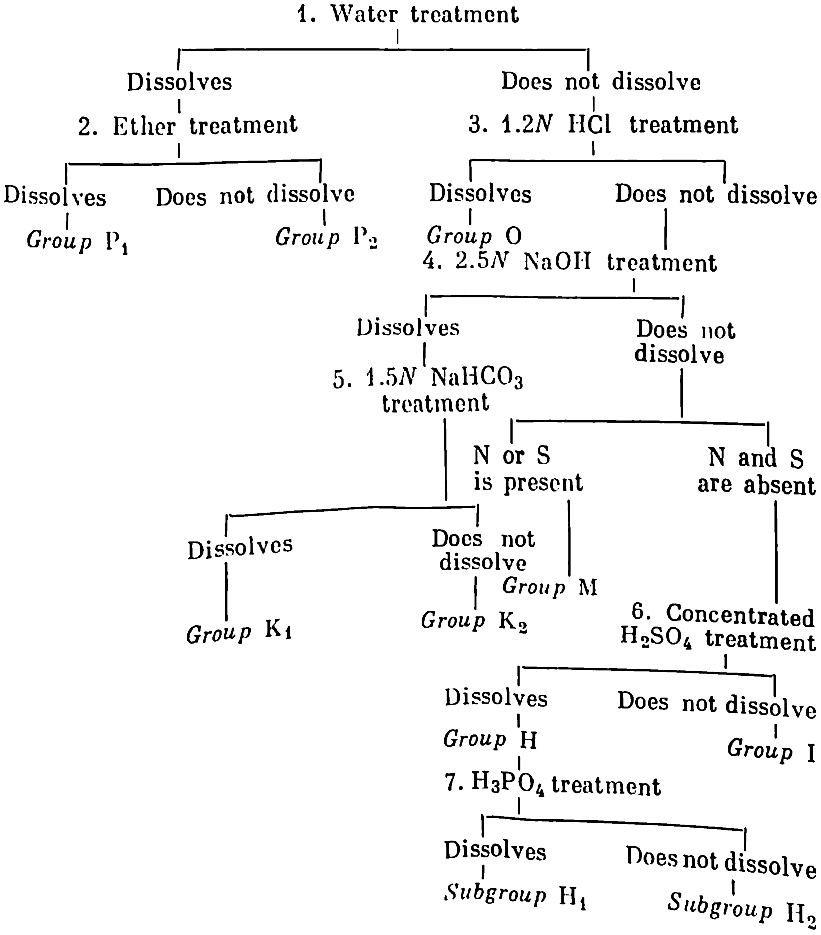


Table 46 (*continued*)

B. Composition of Groups (see Table 46,A)
(the chief compounds of every group are italicized)

Group P_1

Mainly monofunctional compounds with five or less carbon atoms in a molecule.

1. Presence of only C, H and O
    - *Alcohols*
    - *Aldehydes and ketones*
    - *Carboxyl acids*
    - Acetals
    - Anhydrides
    - Ethers and esters
    - Some glycols
    - Lactones
    - Phenols (partially)
2. Presence of N
    - *Amides*
    - *Amines*
    - Heterocyclic amines
    - Nitriles
    - Nitroparaffins
    - Oximes
3. Presence of a halogen
    - Halogen-substituted compounds of subgroup I
4. Presence of S
    - Oxyheterocyclic S-compounds
    - Mercapto acids
    - Thioacids
5. Presence of N and halogens
    - Halogenated amines, amides, nitriles
6. Presence of N and S
    - Aminoheterocyclic compounds

Group P_2

Substances having an average molecular weight, with two or more polar groups (except for sulphonic and sulphinic acids, which belong to the P_2 group, although they have only one polar group in a molecule).

1. Presence of only C, H and O
    - *Dibasic and polybasic acids*
    - *Hydroxyacids*
    - *Polybasic alcohols*
    - *Polybasic phenols*
    - Simple carbohydrates
2. Presence of metals
    - *Acid and phenol salts*
    - Various metal-containing compounds
3. Presence of N
    - *Amine and organic-acid salts*
    - *Amino acids*
    - *Ammonium salts*
    - Amides
    - Amines
    - Amino alcohols
    - Semicarbazides
    - Semicarbazones
    - Ureas
4. Presence of halogens
    - *Halogen acids*
    - Acyl halogenides (as a result of hydrolysis)
    - Halogen alcohols, halogen aldehydes, etc.
5. Presence of S
    - *Sulphonic acids*
    - Alkyl sulphonic acids
    - Sulphinic acids
6. Presence of N and a halogen
    - Amine and halogen-acid salts
7. Presence of N and S
    - Aminodisulphinic acids
    - Hydrosulphates of weak bases
    - Cyanosulphonic acids
    - Nitrosulphonic acids

Table 46 (continued)

Group O: Bases

Diaryl- and triaryl-amines, and also carbazols, belong to the M group. In addition to the listed below the O group includes a small number of oxygen-containing compounds which form oxonium salts when treated with HCl.

Amines (Amines with sufficiently strong negative components belong to the M group)
Amino acids
Amphoteric compounds (aminophenols, aminothiophenols, aminosulphoamides)
Aryl-substituted hydrazines
N-Dialkylamides

Group A_1: Strong Acids

1. Presence of only C, H and O
   - *Acids* (usually, the number of carbon atoms in a molecule is less than 10)
2. Presence of N
   - *Amino acids*
   - *Nitro acids*
   - Cyano acids
   - Heterocyclic nitric and carboxylic acids
   - Polynitrophenols
3. Presence of S
   - *Sulphonic acids*
   - Sulphinic acids
4. Presence of halogen
   - *Halogen acids*
   - Polyhalogenophenols
5. Presence of N and S
   - Aminosulphonic acids
   - Nitrothiophenols
   - Sulphates of weak bases
6. Presence of S and halogens
   - *Sulphohalogenides*

Group A_2: Weak Acids

1. Presence of only C, H and O
   - *Acids* (high-molecular)
   - *Anhydrides*
   - *Phenols* (including esters of phenol acids)
   - Enols
2. Presence of N
   - *Nitrophenols*
   - Amides (including N-monoalkylamides)
   - Aminophenols
   - Amphoteric compounds
   - Cyanophenols
   - Imides
   - N-Monoalkyl aromatic amines
   - N-Substituted hydroxylamines
   - *Amino acids*
   - Oximes
   - Nitroparaffins, primary and secondary
   - Trinitro aromatic hydrocarbons
   - Ureides
3. Presence of halogens
   - *Halogenophenols*
4. Presence of S
   - Mercaptanes
   - Thiophenols
5. Presence of N and halogens
   - Polynitrohalogenated aromatic hydrocarbons
   - Substituted phenols
6. Presence of N and S
   - Aminosulphonamides
   - Aminosulphonic acids
   - Aminothiophenols
   - Sulphamides
   - Thioamides

Table 46 (continued)

Group M

Neutral compounds containing nitrogen or sulphur. Only a few of them are distilled with vapour.

(Only the most common classes are given)

1. Presence of N
   - *Anilides and toluidides*
   - *Amides*
   - *Nitroarylamines*
   - *Nitro hydrocarbons*
   - Aminophenols
   - Azo, hydrazo and azoxy compounds
   - Di- and tri-arylamines
   - Dinitrophenyl hydrazines
   - Nitrates
   - Nitrites
2. Presence of S
   - Mercaptanes
   - N-Dialkyl sulphoamides
   - Sulphates, sulphonates
   - Sulphides, disulphides
   - Sulphones
   - Thioethers
   - Thiourea derivatives
3. Presence of N and S
   - Sulphamides
4. Presence of N and halogen
   - Halogenated amines, amides, nitriles

Group H

Neutral compounds not containing nitrogen and sulphur. Distilled off with vapour. The H_1 subgroup includes compounds containing not more than 7-8 carbon atoms in a molecule; the H_2 subgroup contains the remaining compounds of this group.

Alcohols
Aldehydes and ketones
Esters
Ethers
Unsaturated hydrocarbons
(Acyclic unsaturated hydrocarbons and the cyclic unsaturated hydrocarbons which easily sulphurize)
Acetals
Anhydrides
Lactones
Polysaccharides (they carbonize in concentrated H_2SO_4)

Group I: Inert Compounds

Hydrocarbons (including most cyclic hydrocarbons and all saturated acyclic hydrocarbons)
Halogen derivatives of hydrocarbons
Diaryl ethers

Table 46 (continued)

C. Various Organic Compounds Belonging to the Main Groups

Compound	Group	Compound	Group
Acids		1,2,3,5-Tetramethyl benzene (Isodurene)	H_2
n-Butyric	P_1	1,3,5-Trimethyl benzene (Mesitylene)	H_2
Chloroacetic	P_1	*m*-Xylene	H_2-I
α-Chloropropionic	P_1	*o*-Xylene	H_2-I
Crotonic	P_1	*p*-Xylene	H_2-I
Isovaleric	P_1-K_1	*Amines*	
Valeric	K_1	*n*-Amylamine	P_1
Alcohols		Aniline	O
tert-Amyl	P_1	Benzylamine	P_1
Benzyl	H_1	Diethylamine	P_1
n-Butyl	P_1	Di-*n*-butylamine	O
Cyclopentanol	H_1	Di-*n*-propylamine	P_1-O
Isoamyl	P_1-H_1	Isoamylamine	P_1
Isopropyl methyl carbinol	P_1-H_1	Piperidine	P_1
Aldehydes		Tri-*n*-propylamine	O
n-Butyric	P_1-H_1	*Esters*	
Isobutyric	P_1	Benzyl acetate	H_1
Isovaleric	H_1	*n*-Butyl acetate	H_1
Amides		*sec*-Butyl acetate	H_1
Acetamide	P_1-P_2	*n*-Butyl carbonate	H_1-H_2
Acetanilide	M	*n*-Butyl formate	P_1-H_1
Butyramide	P_1-M	*n*-Butyl oxalate	H_2
Formamide	P_1-P_2	Ethyl acetate	P_1-H_1
Formanilide	P_1-M	Ethyl benzoate	H_2
Isobutyramide	P_1-P_2	Ethyl caprylate	H_2
Propionamide	P_1-P_2	Ethyl carbonate	P_1-H_1
Ethers		Ethyl malonate	H_2
n-Butyl	H_2	Ethyl oxalate	P_1-H_1
Diethyl	P_1-H_1	Ethyl phthalate	H_1
Diisopropyl	H_1	Ethyl succinate	H_1
Ethyl isopropyl	P_1-H_1	Isopropyl acetate	P_1
Ethyl methyl	P_1	Methyl carbonate	P_1-H_1
Aromatic hydrocarbons		Methyl isobutyrate	P_1-H_1
Cymene	I	Methyl isovalerate	H_1
Diphenyl methane	H_2-I	Methyl malonate	P_1-H_1
Naphthalene	I	Methyl propionate	P_1

Table 46 (continued)

Compound	Group	Compound	Group
n-Propyl acetate	P_1-H_1	Methyl-*n*-propyl ketone	P_1-H_1
n-Propyl formate	P_1	Pinacoline	P_1-H_1
Nitriles		Succinonitrile	P_1-P_2-M
n-Butyronitrile	M	Trimethylene cyanide	P_2-M
Isobutyronitrile	P_1-M	*Nitro compounds*	
Propionitrile	P_1	Nitrobenzene	M
Ketones		Nitroethane	K_2
Acetophenone	H_1	Nitromethane	P_1-K_2
Benzophenone	H_2	*Phenols*	
Benzyl ketone	H_2	Chlorohydroquinone	P_1-K_2
Cyclohexanone	P_1-H_1	Hydroquinone	P_1
Cyclopentanone	P_1	Phenol	P_1-K_2
Di-*n*-butyl ketone	H_1-H_2	Phloroglucinol	P_2-K_2
Ethyl methyl ketone	P_1		
Isopropyl methyl ketone	P_1		

D. Widespread Compounds Whose Belonging to a Group Is Dfficult to Foresee

Compound	Group	Compound	Group
Acetal	P_1-H_1	*tert*-Amyl alcohol	P_1
Acetamide	P_1-P_2	*n*-Amylamine	P_1
Acetophenone	H_1	Aniline	O
Acetoxime	P_1	Anthranilic acid	K_1(O)
Acetyl piperidine	P_1	Azelaic acid	K_1
Adipic acid	K_1	Barbituric acid	K_1
Allyl acetate	P_1-H_1	Benzene sulphinic acid	P_1-K_1
Allyl alcohol	P_1	Benzene sulphonic acid	P_2
β-Aminoethyl alcohol	P_2	Benzidine	O
α-Aminoisobutyric acid	P_2	Benzoyl acetone	H_2
m-Aminophenol	P_1-P_2-K_2	Benzoyl carbinol	P_1
o-Aminophenol	P_1-P_2-K_2	Benzyl alcohol	H_1
p-Aminophenol	K_2	Benzylamine	P_1
o-Amino-*p*-valeric acid	K_2(O)	Benzyl malonic acid	P_1-K_1
n-Amyl alcohol	H_1	Benzyl salicylate	K_2
sec-Amyl alcohol	P_1-H_1	Biuret	P_2-M

Table 46 (continued)

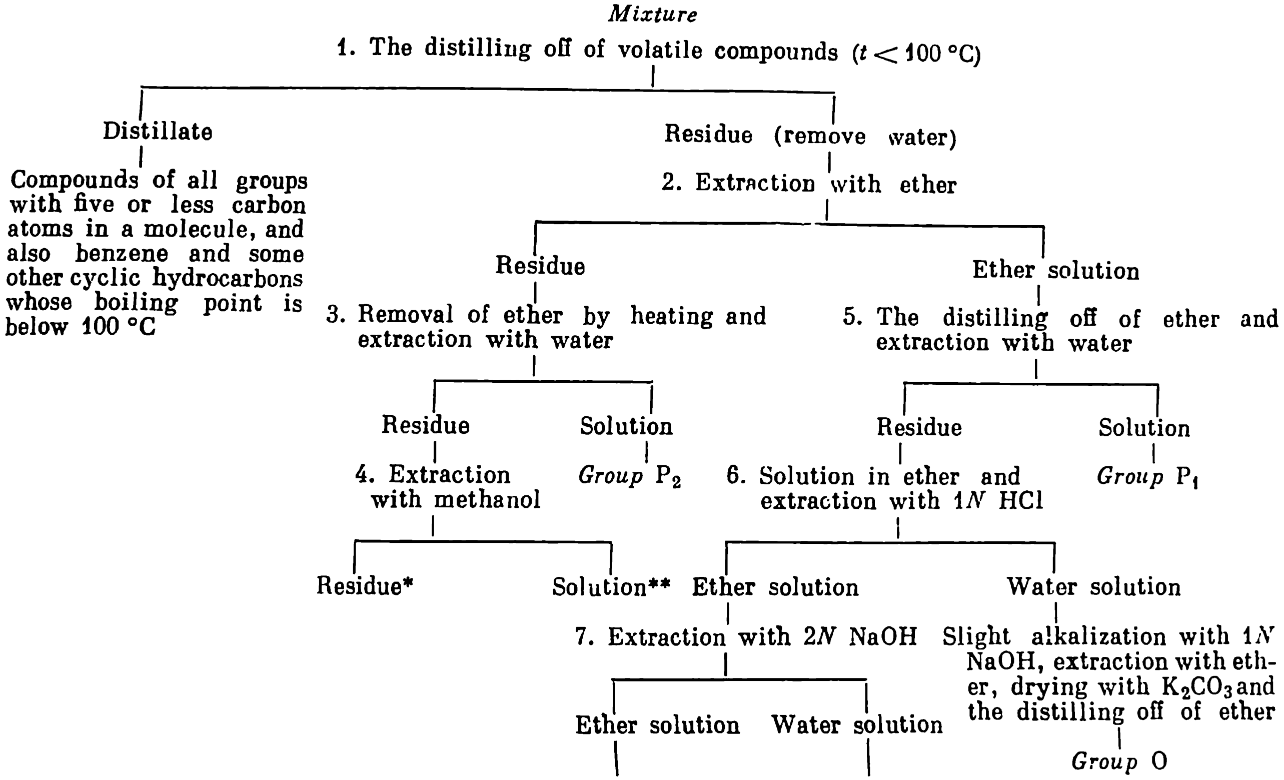
Compound	Group	Compound	Group
Bromal	P_1	Diethylamine	P_1
α-Bromopropionic acid	P_1-K_1	β-Diethyl aminoethyl ether	P_1
n-Butyl acetate	H_1	Diethyl barbituric acid	K_2
sec-Butyl acetate	H_1	Diethyl ether	P_1-H_1
n-Butyl alcohol	P_1	Diethyl ketone	P_1-H_1
n-Butyl carbonate	H_1-H_2	Dimethyl acetal	P_1-H_1
n-Butyl ether	H_2	2,4-Dinitroaniline	O-M
n-Butyl formate	P_1-H_1	Di-*n*-propylamine	P_1-O
n-Butyl oxalate	H_3	Diphenyl methane	H_2-I
n-Butyraldehyde	P_1-H_1	Dioxane	P_1
n-Butyramide	P_1	Durene (1,2,4,5-Tetramethyl benzene)	H_2
n-Butyric acid	P_1	Ethyl acetate	P_1-H_1
n-Butyronitrile	M	Ethyl acetoacetate	P_1
n-Butyryl chloride	P_1-H_1	Ethyl benzoate	H_2
Camphor	H_2	Ethyl carbonate	P_1-H_1
Carbon disulphide	M	Ethyl lactate	P_1-H_1
Chloral	P_1	Ethyl malonate	H_2
β-Chloroethyl acetate	H_1	Ethyl mercaptan	P_1-M
Chlorohydroquinone	P_1-K_2	Ethyl methyl ether	P_1
α-Chloropropionic acid	P_1	Ethyl methyl ketone	P_1
Citric acid	P_2	Ethyl nitrate	P_1-M
Cyanoacetic acid	P_1	Ethyl-*o*-formate	P_1-H_1
Cyclohexanol	H_1	Ethyl oxalate	P_1-H_1
Cyclohexanone	P_1-H_1	Ethyl phthalate	H_1
Cyclohexyl acetate	H_2	Ethyl salicylate	K_2
Cyclohexylamine	P_1	Ethyl succinate	H_1
Cyclopentanol	H_1	Ethylal	P_1-H_1
Cymene	I	Ethylene diamine	P_2
Diacetone alcohol	P_1	Ethylene glycol	P_2
Dibenzoyl methane	H_2	Formamide	P_1-P_2
α,β-Dibromopropionic acid	P_1-K_1	Formanilide	P_1-M
2,5-Dichlorohydroquinone	K_2	Fumaric acid	K_1
α,α-Dichloromethyl ether	P_1	Furfuryl alcohol	P_1
2,6-Dichloro-4-nitroaniline	M	Glutaric acid	P_2
		Glycerin	P_2
		Glycin	P_2
		Guanidine	P_2
		Hydroquinone	P_1

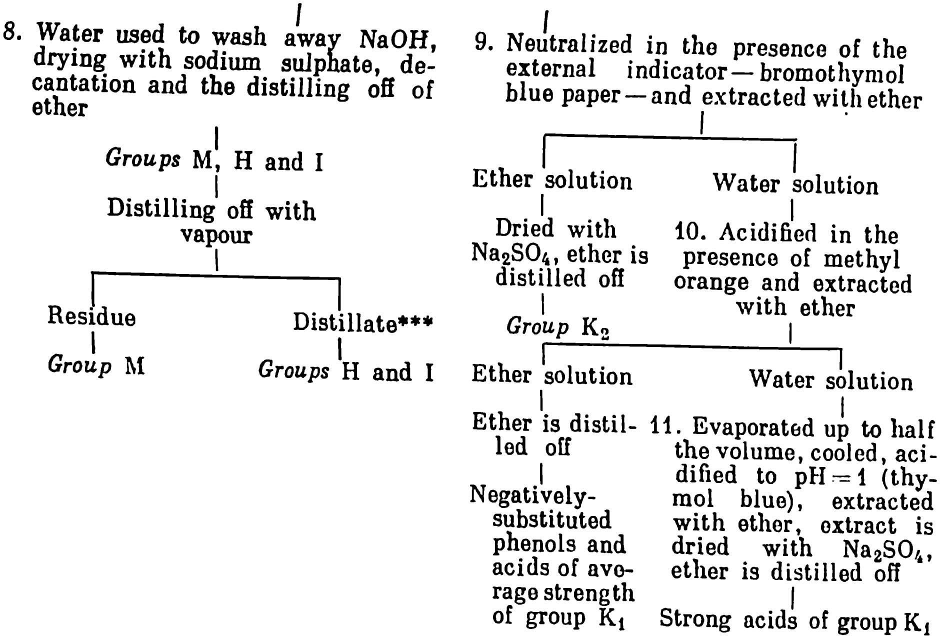
Table 46 (continued)

Compound	Group	Compound	Group
p-Hydroxybenzaldehyde	K_2-H_1	Methyl isovalerate	H_1
o-Hydroxybenzyl alcohol	P_1-K_2	Methyl levulinate	P_1-H_1
Indene	H_2	Methyl malonate	P_1-H_1
Indole	M	Methyl-*n*-butyrate	P_1-H_1
Isoamyl alcohol	P_1-H_1	Methyl nitrate	P_1-M
Isoamylamine	P_1	Methyl-*n*-propyl carbinol	H_1
Isoamyl salicylate	K_2-H_2	Methyl-*n*-propyl ketone	P_1-H_1
Isobutyl formate	P_1	Methyl-*o*-formate	P_1-H_1
Isobutyramide	P_1	Methyl propionate	P_1
Isobutyric aldehyde	P_1	*m*-Nitroaniline	O
Isobutyronitrile	P_1-M	*o*-Nitroaniline	O-M
Isobutyryl chloride	P_1	*p*-Nitroaniline	O
Isodurene (1,2,3,5-Tetramethylbenzene)	H_2	Nitroguanidine	K_2-M
Isopropyl acetate	P_1	Nitromethane	P_1-K_2
Isopropyl methyl ketone	P_1	*p*-Nitrosodiphenylamine	K_2-M
Isovaleric aldehyde	H_1	Nitrourea	K_2-M
Isovaleryl chloride	P_1-H_1	Oxamide	M
Lactic acid	P_2	Paraldehyde	P_1-H_1
Maleic acid	P_1-P_2	Phenol	P_1-K_2
Malonic acid	P_1	Phenoxyacetic acid	P_1-K_1
Mandelic acid	P_1	*m*-Phenylenediamine	P_1-P_2
Mesitylene	H_2	*o*-Phenylenediamine	P_1-P_2
Mesityl oxide	H_1	*p*-Phenylenediamine	P_2
N-Methyl acetanilide	O-M	Phenyl hydrazine	O
Methyl acetoacetate	P_1	Phloroglycinol	P_2-K_2
Methylal	P_1-H_1	Phthalic acid	K_1
N-Methyl benzylamine	O	Phthalic anhydride	H_1
Methyl carbonate	P_1-H_1	Phthalimide	K_2
Methyl chloroacetate	P_1-H_1	Picric acid	K_1
Methyl citrate	P_1-H_1	Pimelic acid	P_1-K_1
Methyl isobutyrate	P_1-H_1	Pinacol	P_1
		Piperidine	P_1
		Polyoxymethylene	P_2-H_2
		Propionamide	P_1-P_2

Table 46 (continued)

Compound	Group	Compound	Group
Propionitrile	P_1	2,4,6-Tribromophenol	K_1
Propionyl chloride	P_1	2,4,6-Trichloroaniline	O-M
n-Propyl acetate	P_1-H_1	2,4,6-Trichlorophenol	K_1
n-Propyl formate	P_1	Trimethylene glycol	P_2
Propylene glycol	P_1	Trimethylene cyanide	P_2-M
Protocatechuic aldehyde	P_1-K_2	Tri-*n*-propylamine	O
Pyridine	P_1	α-Triphenyl guanidine	O-M
Pyrocatechin	P_1	Urea	P_2
Pyrrole	M	Vanillin	K_1
Resorcinol	P_1	*n*-Valeric acid	K_1
Sebacic acid	K_1	*n*-Valeric aldehyde	H_1
Succinimide	P_1-P_2	Xylenes	H_2-I
Succinnitrile	P_1-P_2-M		
Sulphanilic acid	K_1		
Triacetin (glycerin triacetate)	P_1-H_1		
2,4,6-Tribromoaniline	M		


Mixture
1. The distilling off of volatile compounds ($t < 100$ °C)
Distillate
Compounds of all groups with five or less carbon atoms in a molecule, and also benzene and some other cyclic hydrocarbons whose boiling point is below 100 °C
Residue (remove water)
2. Extraction with ether
Residue
3. Removal of ether by heating and extraction with water
Residue
4. Extraction with methanol
Residue*
Solution**
Solution
Group P_2
Ether solution
5. The distilling off of ether and extraction with water
Residue
6. Solution in ether and extraction with 1N HCl
Ether solution
7. Extraction with 2N NaOH
Ether solution
Water solution
Water solution
Slight alkalization with 1N NaOH, extraction with ether, drying with K_2CO_3 and the distilling off of ether
Group O
Solution
Group P_1



8. Water used to wash away NaOH, drying with sodium sulphate, decantation and the distilling off of ether

Groups M, H and I

Distilling off with vapour

Residue — *Group* M

Distillate*** — *Groups* H and I

9. Neutralized in the presence of the external indicator — bromothymol blue paper — and extracted with ether

Ether solution — Dried with Na_2SO_4, ether is distilled off — *Group* K_2

Water solution — 10. Acidified in the presence of methyl orange and extracted with ether

Ether solution — Ether is distilled off — Negatively-substituted phenols and acids of average strength of group K_1

Water solution — 11. Evaporated up to half the volume, cooled, acidified to pH = 1 (thymol blue), extracted with ether, extract is dried with Na_2SO_4, ether is distilled off — Strong acids of group K_1

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* This residue may contain: many dinitro-derivatives of aromatic hydrocarbons and their amino-, oxy- and acid derivatives; many trinitro compounds of the aforementioned types; some dihalogen derivatives of anthracene, some amino-substituted sulphonic acids, a few amides and imides; benzyl- and benzoylureas, some derivatives of anthraquinone.

** This solution may contain: some dibromo- and dinitrobenzoic acids; a few other aromatic acids; some polyoxy- and polyaminoquinones and quinolines, a few aminophenols, amides and anilides; very few amines.

*** To separate group I, use can be made of the inertness of the compounds which belong to this group, oxidizing the compounds of group H, binding aldehydes and ketones by the saturated $NaHSO_4$ solution, and other methods. The presence of group I can be determined with the aid of concentrated H_2SO_4 using a part of the test.

Table 47

Substances Used for Drying

A. Drying of Gases

Substance	Characteristics	Amount of steam, mg, remaining in 1 litre of gas upon passing it at a rate of 1-5 l/h; t=30.5 °C
$CuSO_4$	Anhydrous	2.8
$CaCl_2$	Granulated; average composition: $CaCl_2 \cdot H_2O$	1.5
$CaCl_2$	Technically anhydrous; average composition: $CaCl_2 \cdot 1/4H_2O$	1.25
$ZnCl_2$	Stick	0.98
$Ba(ClO_4)_2$	Anhydrous	0.82
$NaOH$	Stick	0.80
$CaCl_2$	Anhydrous	0.36
$Mg(ClO_4)_2 \cdot 3H_2O$	—	0.031
KOH	Stick	0.014
Silica gel	—	0.006
$CaSO_4$	Anhydrous	0.005
CaO	—	0.003
H_2SO_4	100%	0.003
$Mg(ClO_4)_2$	Anhydrous	0.002
Al_2O_3	—	0.001
BaO	—	0.0007
P_2O_5	—	0.00003

B. Drying of Liquids

Liquid	Drier
Acids	Na_2SO_4
Alcohols	K_2CO_3, $CuSO_4$, CaO, Na_2SO_4 (but not $CaCl_2$, CaC_2)
Aldehydes	$CaCl_2$, $Mg(ClO_4)_2$
Amines	$NaOH$, KOH, K_2CO_3 (but not $CaCl_2$)
Bases	KOH, K_2CO_3, BaO
Carbon disulphide	$CaCl_2$, $Mg(ClO_4)_2$
Esters	Na_2SO_4, $CaCl_2$, $Mg(ClO_4)_2$
Ethers	$CaCl_2$, Na, CaC_2, K_2CO_3, $Mg(ClO_4)_2$
Hydrazines	K_2CO_3
Hydrocarbons	$CaCl_2$, Na, CaC_2, $Mg(ClO_4)_2$
halogen-derivative ones	$CaCl_2$, $Mg(ClO_4)_2$ (but not Na)
Ketones	K_2CO_3, $CaCl_2$, $Mg(ClO_4)_2$ (for higher ketones)
Nitriles	K_2CO_3
Nitro compounds	$CaCl_2$, Na_2SO_4, $Mg(ClO_4)_2$
Phenols	Na_2SO_4

Table 48

Preparation of Hygrostats

Relative pressure of water vapour over mixtures of solid salts with their saturated aqueous solutions, over mixtures of anhydrous salts with their hydrates and over mixtures of two differing hydrates; water vapour pressure at a given temperature is taken as unity.

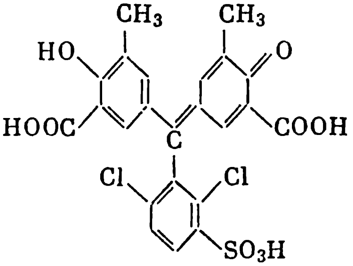
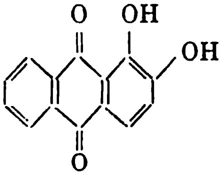
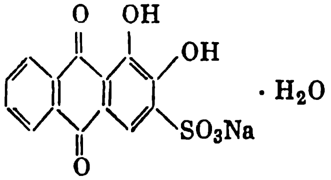
Mixture	Temperature, °C				
	10	15	20	25	30
	relative water vapour pressure				
P_2O_5	—	—	< 0.01	—	—
KOH	—	—	0.05	—	—
$NaOH$	—	—	0.06	—	—
$CaBr_2 \cdot 6H_2O$	0.23	0.21	0.19	0.17	0.15
$CaCl_2 \cdot 6H_2O$	0.38	0.35	0.32	0.29	0.26
$K_2CO_3 \cdot 2H_2O$	—	—	0.44	0.45	—
$Ca(NO_3)_2 \cdot 4H_2O$	0.65	0.60	0.55	0.50	0.45
$NaBr \cdot 2H_2O$	0.63	0.61	0.59	0.57	0.55
NH_4NO_3	0.69	0.66	0.63	0.60	0.57
$NaCl$	0.75	0.75	0.75	0.75	0.75
$NaNO_3$	0.77	0.76	0.75	0.74	0.73
KCl	—	—	0.86	0.85	0.85
$Na_2SO_4 \cdot 10H_2O$	—	0.95	0.90	0.85	0.78
$Na_2CO_3 \cdot 10H_2O$	—	—	0.91	0.89	0.87
KNO_3	—	—	0.95	0.94	0.94
$Na_2B_4O_7 \cdot 10H_2O$	—	—	0.99	—	—
$MgCl_2 + MgCl_2 \cdot 2H_2O$	—	—	0.0005	—	—
$KOH + KOH \cdot H_2O$	—	—	—	—	0.02
$CaCl_2 + CaCl_2 \cdot H_2O$	—	—	0.15	—	—
$Na_2SO_4 + Na_2SO_4 \cdot 10H_2O$	0.69	0.72	0.76	0.80	—
$NaOH + NaOH \cdot H_2O$	—	—	0.03	—	—
$K_2CO_3 + K_2CO_3 \cdot 2H_2O$	—	—	—	0.05	—
$NaI + NaI \cdot 2H_2O$	—	0.12	0.13	0.14	0.15
$Na_2CO_3 + Na_2CO_3 \cdot H_2O$	—	—	—	0.20	—
$Na_2B_4O_7 + Na_2B_4O_7 \cdot 5H_2O$	—	—	0.25	—	—
$Na_2HPO_4 + Na_2HPO_4 \cdot 2H_2O$	—	0.27	0.28	0.29	—
$NaBr + NaBr \cdot 2H_2O$	0.30	0.32	0.34	0.36	0.38
$CaCl_2 \cdot H_2O + CaCl_2 \cdot 2H_2O$	—	0.05	—	—	—
$CaCl_2 \cdot 2H_2O + CaCl_2 \cdot 6H_2O$	0.21	0.21	0.22	0.22	0.23
$Na_2B_4O_7 \cdot 5H_2O + Na_2B_4O_7 \times 10H_2O$	—	—	0.39	—	—
$Na_2HPO_4 \cdot 2H_2O + Na_2HPO_4 \times 7H_2O$	0.50	0.53	0.56	0.59	0.62
$Na_2CO_3 \cdot H_2O + Na_2CO_3 \cdot 10H_2O$	0.66	0.69	0.72	0.76	—
$Na_2HPO_4 \cdot 7H_2O + Na_2HPO_4 \times 12H_2O$	0.65	0.70	0.75	0.81	—

Table 49

Principal Organic Reagents

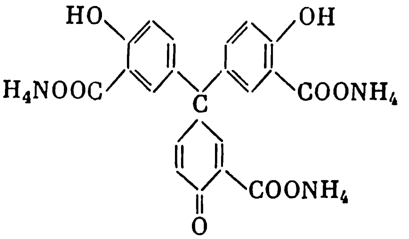
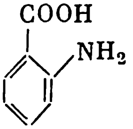
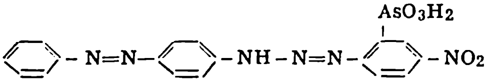
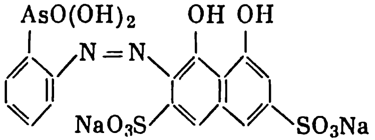
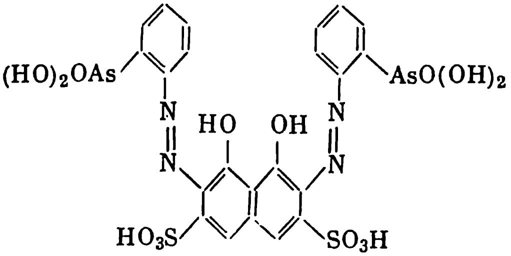
Abbreviations used: grav. for gravimetric analysis; vol. for volumetric and similar analyses. In cases of gravimetric and volumetric one atom of a metal is given in parentheses in the sixth column.

A. In the Alphabetical Order of the Reagents

No.	Reagent	Synonymous names
1	Alberon 	Dichlorosulphodimethyloxyfuchsone dicarboxylic acid; chromoxane pure blue dye BLD
2	Alizarin 	1,2-Dioxyanthraquinone
3	Alizarin Red S 	Alizarin S; sodium alizarin sulphonate; 1,2-dihydroxyanthraquinone-3-sulphoni c acid, sodium salt

metric analysis; phot. for colorimetric, spectrophotometric, fluoro-determinations, the number of molecules of a reagent bounded with

Molecular weight		Elements being determined	Method
M	log M		
539.35	73 188	Be^{2+}, Al^{3+}	Phot.
240.22	38 061	Al^{3+}, Zr^{IV}, Th^{IV}, F^-	Phot.
360.28	55 664	Al^{3+}, Zr^{IV}, Th^{IV}, Ga^{3+}, F^-, Ti^{IV}, UO_2^{2+}	Phot.

No.	Reagent	Synonymous names
4	Aluminon 	Ammonium salt of aurine tricarboxylic acid
5	Anthranilic acid 	*o*-Aminobenzoic acid
6	Arsasene 	1″, 4-Diazoamino-1,1′-azobenzene-4″-nitrobenzene arsonic acid-2″
7	Arsenazo I 	Benzene-2′-arsonic acid-(1′-azo-2)-1,8-dihydroxynaphthalene-3,6-disulphonic acid, disodium salt; uranon
8	Arsenazo III 	Benzene-2′-arsonic acid-(1′-azo-2)-benzene-2″-arsonic acid-(1″-azo-7)-1,8-dihydroxynaphthalene-3,6-disulphonic acid

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* RE: rare-earth elements (lanthanoids, Y and Sc).

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log *M*		
473.45	67 528	Al^{3+}, F^-, Be^{2+}	Phot.
137.14	13 716	Cd^{2+}, Co^{2+}, Cu^{2+}, Hg^{2+}, Mn^{2+}, Ni^{2+}, Pb^{2+}, Zn^{2+} (in the form of MeR_2)	Grav.
470.28	—	Pb^{2+}, Zn^{2+}	Phot.
592.30	77 254	Al^{3+}, Be^{2+}, Ce^{IV}, In^{3+}, Nb^V, RE*, Ta^V, Th^{IV}, Ti^{IV}, UO_2^{2+}, V^{IV}, Zr^{IV}	Phot.
776.38	89 008	Ce^{IV}, Hf^{IV}, Np^{IV}, Pa^V, Pu^{IV}, RE*, Th^{IV}, U^{IV}, UO_2^{2+}, Zr^{IV}	Phot.

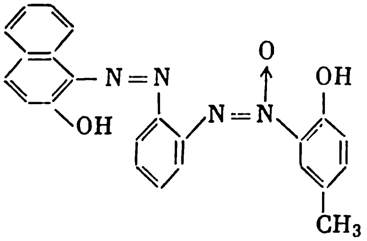
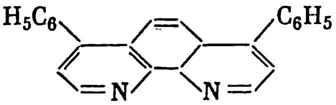
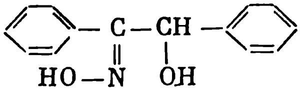
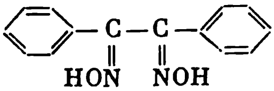
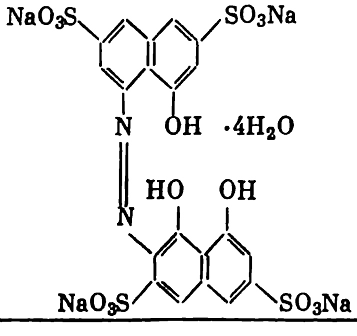
No.	Reagent	Synonymous names
9	Azo-azoxy BN 	2-[2″-Hydroxynaphthalene-(1″-azo-2′)-phenylazoxy]-4-methylphenol
10	Bathophenanthroline 	4,7-Diphenyl-1-10-phenanthroline
11	α-Benzoin oxime 	Cupron
12	α-Benzyl dioxime 	α-Diphenyl dioxime, nickelon
13	Beryllon II 	3,6-Disulphonaphthol-(8-azo-7′)-1′, 8′-dioxy-3′, 6′-disulphonaphthalene, tetrasodium salt

Table 49 (continued)

	Molecular weight		Elements being determined	Method
	M	log *M*		
	398.43	60 035	Ca^{2+}	Phot.
	350.44	54 461	Fe^{2+}	Phot.
	227.27	35 654	Cu^{2+} (in the form of MeR_2)	Grav.
	240.27	38 070	Ni^{2+} (in the form of MeR_2)	Grav.
	810.58	90 882	Be^{2+}	Phot.

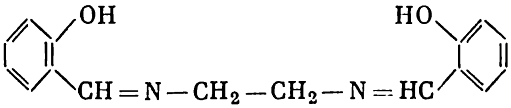
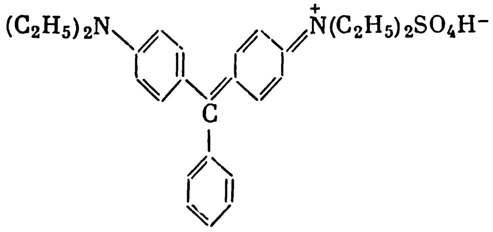
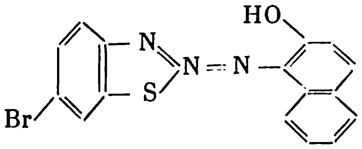
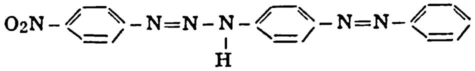
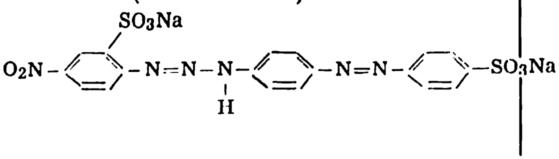
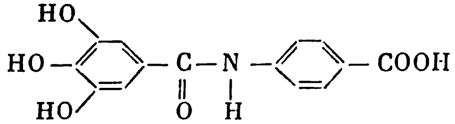
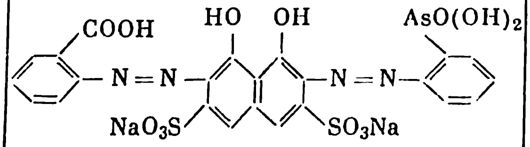
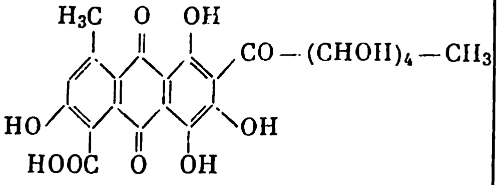
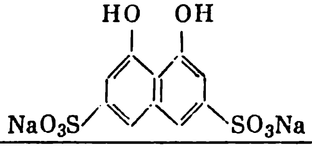
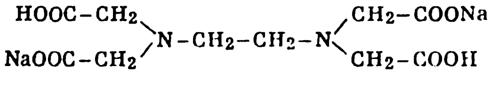
No.	Reagent	Synonymous names
14	Bis-salicylalethylenediamine 	—
15	Brilliant green 	—
16	Bromobenzothiazo 	—
17	Brucine $C_{23}H_{26}O_4N_2$	—
18	Cadion 	*p*-Nitrophenylazoaminobenzene-*p*-azobenzene
19	Cadion S (water-soluble) 	—

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
268.32	42 865	Mg^{2+}	Phot. (luminescence)
482.65	68 363	Sb^{V}, Tl^{3+}, Zn^{2+}	Phot.
372.25	57 083	Cd^{2+}	Phot.
394.48	59 603	NO_3^-	Phot.
346.35	53 952	Cd^{2+}	Qualitative (phot.)
550.46	74 073	Cd^{2+}	Phot.

No.	Reagent	Synonymous names
20	*p*-Carboxygallanilide 	3, 4, 5-Trioxybenzoyl-para-aminobenzoic acid
21	Carboxyarsenazo  COOH HO OH AsO(OH)$_2$ N=N N=N NaO$_3$S SO$_3$Na	2-Phenylcarboxylic acid-(1-azo-2′) 1′,8′-dioxynaphthalene-3′, 6′-disulphonic acid-(7′-azo-1″) 2″-phenylarsonic acid, disodium salt
22	Carminic acid  H$_3$C O OH CO—(CHOH)$_4$—CH$_3$ HO OH HOOC O OH	—
23	Chromotropic acid, disodium salt 	1, 8-Dioxynaphthalene-3, 6-disulphonic acid, disodium salt
24	**Complexone III**  $\mathrm{(HOOC{-}CH_2)(NaOOC{-}CH_2)N{-}CH_2{-}CH_2{-}N(CH_2{-}COONa)(CH_2{-}COOH)}$	EDTA (sodium ethylenediaminetetraacetate, trilon B, versene, chelaton 3)

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* RE: rare-earth elements (lanthanoids, Y and Sc).

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log *M*		
289.25	46 126	Ti^{IV}	Phot.
740.30	86 941	Ba^{2+}, SO_4^{2-}	Vol.
492.40	69 232	B^{III}	Phot.
364.27	56 142	Ti^{IV}, Cr^{VI}	Phot.
336.22	52 663	Ca^{2+}, Mg^{2+}, Ni^{2+}, Cu^{2+}, Ag^{+}, Au^{3+}, Pd^{2+}, Co^{2+}, V^{IV}, Bi^{3+}, Ga^{3+}, In^{3+}, Sn^{2+}, RE*, Sc^{3+}, Sr^{2+}, Ti^{IV}, Th^{IV}, Cr^{3+}, Zr^{IV}, Mn^{2+}, Ba^{2+}, Zn^{2+}, Cd^{2+}, Pb^{2+}, Hg^{2+}, Tl^{3+}, Fe^{2+}, Al^{3+}, Fe^{3+} (in the form of MeR) Cr^{3+}, Co^{2+}, Mn^{2+}	Vol. Phot.

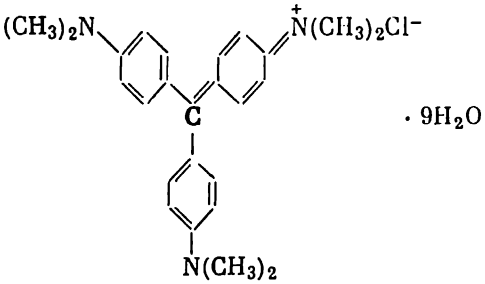
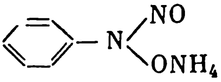
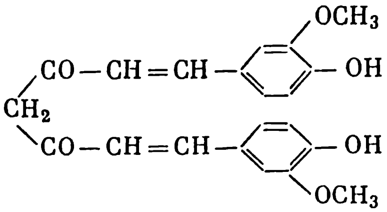
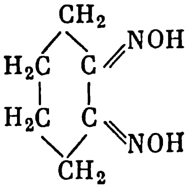
No.	Reagent	Synonymous names
25	Crystal violet 	—
26	Cupferron 	N-Nitrosophenylhydroxylamine, ammonium salt
27	Curcumin 	Bis-(4-hydroxy-3-methoxycinnamoyl)-methane
28	Cyclohexane diondioxime-1,2 	Nioxime
29	Diallyldithiocarbamidohydrazine $C_3H_5NHCSNHNHCSNHC_3H_5$	—

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
570.14	75 598	Sb^{V}, Zn^{2+}, Tl^{3+}, Cd^{2+}, Hg^{2+}	Phot.
155.16	12 078	Al^{3+}, Bi^{3+}, Cu^{2+}, Fe^{3+}, Ga^{3+}, Nb^{V}, Sn^{IV}, Ta^{V}, Ti^{IV}, Th^{IV}, V^{V}, Zr^{IV}, U^{IV} (in the form of MeR_n, where n is the valency of metal; or the precipitates are calcined to the oxides)	Grav.
368.39	56 631	B^{III}, Be^{2+}	Phot.
142.16	15 278	Ni^{2+}, Fe^{2+}, Pd^{2+}	Phot.
230.36	36 241	Cu^{2+}, Pb^{2+}, Zn^{2+}, Ni^{2+}, Ag^{+}	Grav.

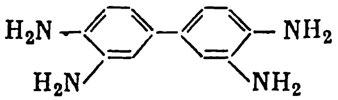
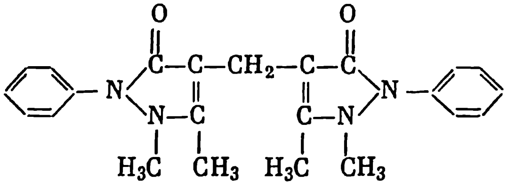
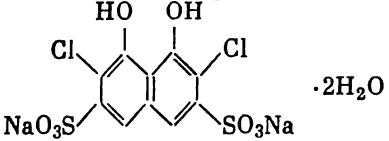
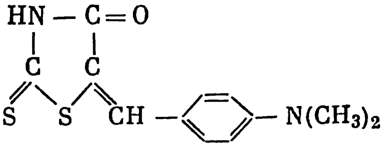
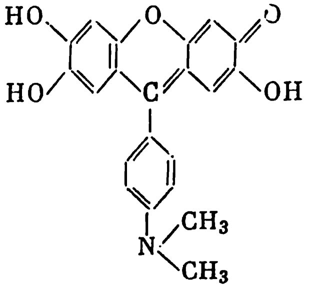
No.	Reagent	Synonymous names
30	3, 3'-Diaminobenzidine 	Tetraaminodiphenyl
31	Diantipyryl methane 	—
32	2, 7-Dichlorochromotropic acid 	1, 8-Dioxy-2, 7-dichloronaphthalene-3, 6-disulphonic acid, disodium salt
33	*p*-Dimethylaminobenzylidene rhodanine 	—
34	*p*-Dimethylaminophenylfluorone 	Dimethyl fluorone; 2, 6, 7-trioxy-9-(4''-dimethylaminophenyl)-3-fluorone

Table 49 (*continued*)

Molecular weight		Elements being determined	Method
M	log M		
214.28	33 098	Se^{IV}	Phot.
388.48	58 937	Cd^{2+}, Ti^{IV}, Fe^{3+}, Bi^{3+}, Co^{2+}	Grav.
469.18	67 134	Ti^{IV}	Phot.
264.38	42 223	Ag^+, Au^+, Hg^{2+}, Pd^{2+}, Cu^+ Ag^+, Pt^{IV}, CN^-	Phot. Vol.
363.37	56 035	Ta^V	Phot.

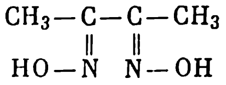
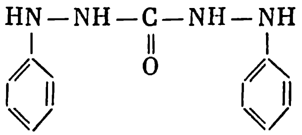
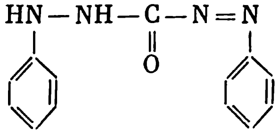
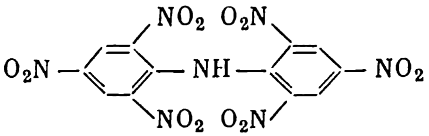
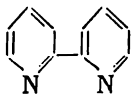
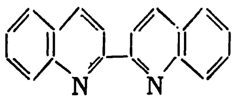
No.	Reagent	Synonymous names
35	Dimethylglyoxime  $CH_3-\underset{\underset{HO-N}{\|}}{C}-\underset{\underset{N-OH}{\|}}{C}-CH_3$	Diacetyl dioxime, Chugaev's reagent
36	Diphenylcarbazide 	1, 5-Diphenylcarbohydrazide
37	Diphenylcarbazone 	—
38	Dipicrylamine 	Hexanitrodiphenylamine
39	2, 2′-Dipyridyl 	α, α′-Dipyridyl
40	2, 2′-Diquinolyl 	2, 2′-Diquinoline; cuproin

Table 49 (*continued*)

	Molecular weight		Elements being determined	Method
	M	$\log M$		
	116.12	06 491	Ni^{2+}, Pd^{2+} (in the form of MeR_2) Fe^{2+}, Co^{2+}, Cu^{2+} (together with pyridine)	Grav., vol., phot. Phot.
	242.29	98 433	Cr^{VI}, Hg^{2+}, Pb^{2+} (indirect), (Cd^{2+})	Phot.
	240.27	38 070	Hg^{2+}, Ag^{+}	Phot.
	439.23	64 269	K^{+}, Rb^{+}, Cs^{+} (in the form of MeR)	Grav., phot.
	156.19	19 365	Fe^{2+}	Phot.
	256.30	40 875	Cu^{+}, (Ti^{3+})	Phot.

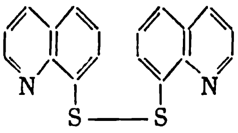
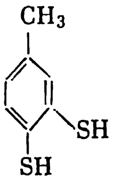
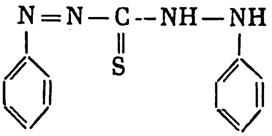
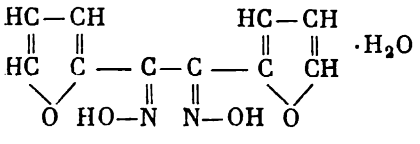
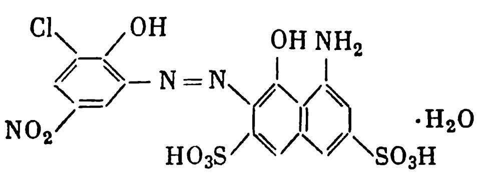
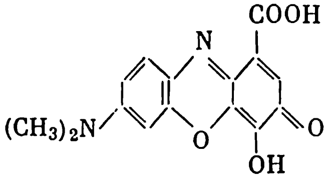
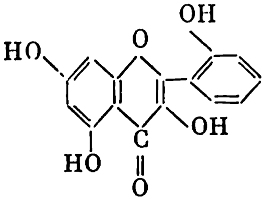
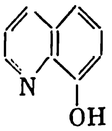
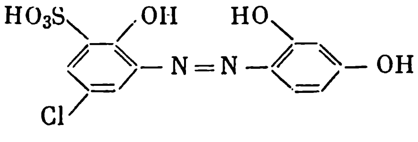
No.	Reagent	Synonymous names
41	8, 8′-Diquinolyldisulphide 	—
42	Dithiol 	1-Methyl-3,4-dimercaptobenzene
43	Dithizone 	Diphenylthiocarbazone
44	Eriochrome Cyanine R *See* Table 28, No. 23 (p. 232)	
45	α-Furfuryl dioxime 	Neoniclon
46	Gallion 	2-Hydroxy-3-chloro-5-nitrobenzene-(1-azo-2′)-1′-hydroxy-8′-naphthylamine-3′, 6′-disulphonic acid

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
320.44	50 575	Cu^+	Phot.
156.27	19 388	Sn^{2+}, W^{VI}, Mo^{VI}	Phot.
256.34	40 882	Ag^+, Bi^{3+}, Cd^{2+}, Co^{2+}, Cu^{2+}, Hg^{2+}, Pb^{2+}, Zn^{2+}, Ni^{2+}, In^{3+}, Tl^+, Sn^{2+}	Phot.
470.46	67 252	Al^{3+}, Be^{2+}, Zr^{IV}, F^-	Phot.
238.21	37 696	Ni^{2+}, Pd^{2+} (in the form of MeR_2), Pt^{IV}, Re^{VII}	Grav., phot.
536.88	72 989	Ga^{3+}	Phot.

No.	Reagent	Synonymous names
47	Gallocyanine 	—
48	Hemp-like datisca (extract) 	Substitute for morin. Parent substance: 3, 5, 7, 2′-tetraoxyflavone
49	8-Hydroxyquinoline 	*o*-Hydroxyquinoline, oxine
50	Lumogallion 	2, 2′, 4′-Trioxy-5-chloro-(1-azo-1′)-benzene-3-sulphonic acid

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* Thorium and uranium precipitate in the form of $ThR_4 \cdot HR$ and

Table 49 (continued)

	Molecular weight		Elements being determined	Method
	M	$\log M$		
	300.27	47 751	Ga^{3+}, Hg^{2+}, Pb^{2+}	Vol. (complexonometry)
	286.25	45 675	Al^{3+}, Ga^{3+}, Zr^{IV}, Th^{IV}	Phot. (luminescence)
	145.16	16 185	Al^{3+}, Mg^{2+}, Zn^{2+}, Bi^{3+}, Cd^{2+}, Co^{2+}, Cu^{2+}, Ga^{3+}, In^{3+}, TiO^{2+}, Zr^{4+}, MoO_2^{2+}, WO_2^{2+}, Mn^{2+}, Fe^{3+}, Ni^{2+}, $V_2O_3^{4+}$, Pb^{2+}, Pd^{2+}, Sb^{3+}, Cr^{3+} (in the form of MeR_n, where n is the valency of metal)*	Grav., vol., phot.
	344.74	53 749	Ga^{3+}	Phot. (luminescence)

$UO_2R_2 \cdot HR$; niobium precipitate is of an unknown composition.

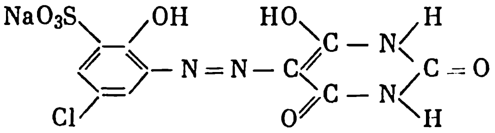
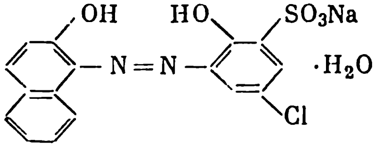
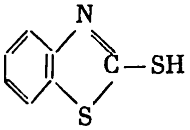
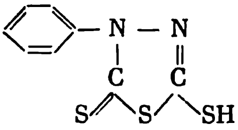
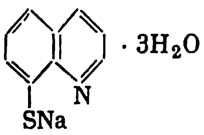
No.	Reagent	Synonymous names
51	Lumomagneson 	2-Hydroxy-3-sulpho-5-chlorobenzene-1-azobarbituric acid
52	Magneson CS 	2-Naphthol-(1-azo-2')-4'-chlorophenol-6'-sodium sulphonate
53	Mercaptobenzothiazole 	Captax
54	Mercaptophenylthiothiodiazolone 	5-Mercapto-3-phenyl-2-thio-1, 3, 4-thiodiazolone; bismuthol II
55	8-Mercaptoquinoline, sodium salt 	Thiooxine, thioxine

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
384.69	58 511	Mg^{2+}	Phot. (luminescence)
418.79	62 201	Mg^{2+}, Zn^{2+}	Phot.
167.26	22 341	Ag^{+}, Au^{3+}, Bi^{3+}, Cd^{2+}, Cu^{2+}, Pb^{2+}, Tl^{3+}	Grav.
226.35	35 478	Bi^{3+}	Phot.
237.25	37 521	Pd^{2+}, Cu^{2+}, Mo^{VI}, Re^{VII}, In^{3+}, Mn^{2+}, V^{IV}, Co^{2+}, Ru^{3+}, Os^{3+}, Tl^{+}	Phot.

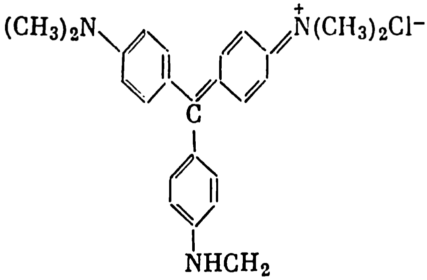
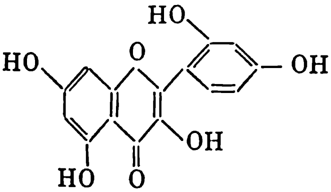
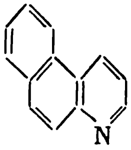
No.	Reagent	Synonymous names
56	Methyl violet  (predominantly)	—
57	Morin 	3, 5, 7, 2′, 4′-Pentaoxyflavone
58	Murexide, *See* Table 28, No. 33, p. 238	
59	β-Naphthoquinoline 	Naphthin, 5, 6-benzoquinoline

Table 49 (continued)

	Molecular weight		Elements being determined	Method
	M	log M		
	—	—	Sb^{V}, Zn^{2+}, Cd^{2+}, Ti^{3+}, Hg^{2+}, Re^{VII}, Ta^{V}	Phot.
	298.26	47 459	Al^{3+}, Ca^{3+}, Zr^{IV}, Th^{IV}, In^{3+}	Phot. (luminescence)
	302.21	48 031	Ca^{2+}, Sr^{2+}	Phot.
	179.22	25 339	Cd^{2+} (the precipitate is calcined to the oxide)	Grav.

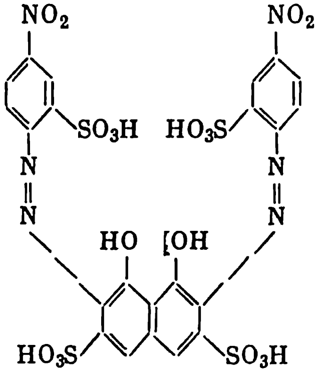
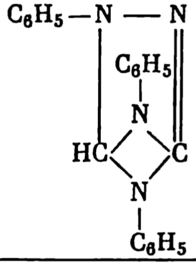
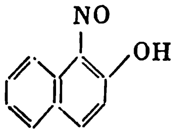
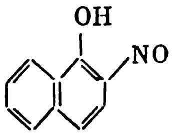
No.	Reagent	Synonymous names
60	Nitrochromoazo 	Bis-[2, 7-(4-nitro-2-sulpho-1-azobenzene)]-1, 8-dioxynaphthalene-3, 6,-disulphonic acid
61	Nitron 	1,4-Diphenyl-(3,5-endoanyl)-dihydro-1, 2, 4-triazole
62	α-Nitroso-β-naphthol 	Ilyinsky's reagent; 1-nitroso-2-naphthol
63	β-Nitroso-α-naphthol 	2-Nitroso-1-naphthol

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
778.65	89 134	Ba^{2+}, SO_4^{2-}	Vol.
312.38	49 468	ReO_4^-, NO_3^-, ClO_3^-, ClO_4^- (in the form of RAn, where An is an anion)	Grav.
173.17	23 848	Co^{2+}, Fe^{3+}, Pd^{2+}, Cu^{2+} (in the form of MeR_n, where n is the valency of metal; otherwise the precipitates are calcined to the oxides)	Grav., phot.
173.17	23 848	Co^{2+}	Phot.

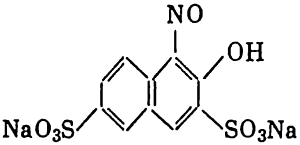
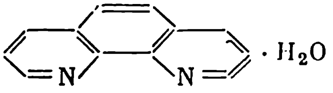
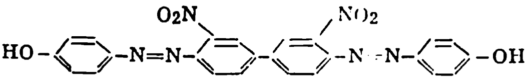
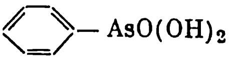
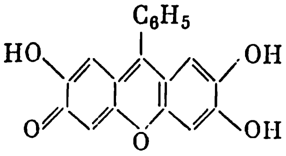
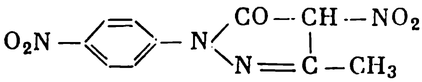
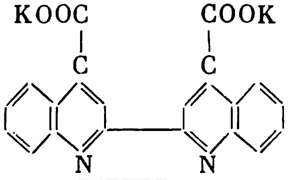
No.	Reagent	Synonymous names
64	Nitroso-R-salt 	1-Nitroso-2-naphthol-3, 6-disulphonic acid, disodium salt
65	1, 10-Phenanthroline 	—
66	Phenazo 	3, 3'-Dinitro-4, 4'-bis-(4''-hydroxybenzeneazo)-biphenyl
67	Phenylarsonic acid 	—
68	Phenylfluorone 	9-Phenyl-2, 3, 7-trioxyfluorone-6
69	Picrolonic acid 	1-(*p*-Nitrophenyl)-3-methyl-4-nitropyrazolone-5
70	2, 2'-Potassium bicinchonine 	—

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
377.27	57 665	Co^{2+}, K^+ (indirect)	Phot.
198.23	29 717	Fe^{2+}	Phot.
484.30	68 511	Mg^{2+}	Phot.
202.03	30 542	Nb^V, Ta^V, Zr^{IV}, Bi^{3+}, Hf^{IV}, Sn^{IV}, Th^{IV} (precipitates are calcined to the oxides)	Grav.
320.31	50 557	Ge^{IV}, Sn^{IV}, Ta^V, Zr^{IV}, Sb^{III}	Phot.
264.21	42 195	Pb^{2+}, Ca^{2+}, Sr^{2+}, Mg^{2+}, Th^{IV} (in the form of MeR_n, where n is the valency of metal) Ca^{2+}	Grav. Phot.
420.52	62 379	Cu^+	Phot.

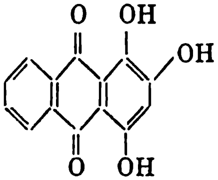
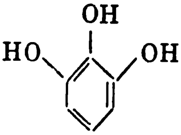
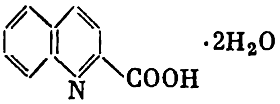
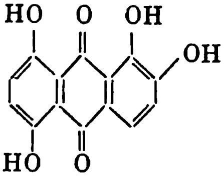
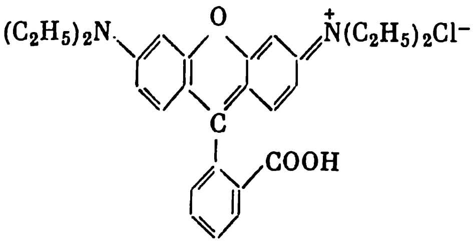
No.	Reagent	Synonymous names
71	Purpurin 	1, 2, 4-Trioxyanthraquinone
72	Pyrogallol 	1, 2, 3-Trioxybenzene
73	Quinaldic acid 	α-Quinoline carboxylic acid
74	Quinalizarin 	1, 2, 5, 8-Tetraoxyanthraquinone
75	Rhodamine B 	Rhodamine S: tetraethyldiamino-*o*-carboxyphenylxanthenyl chloride

Table 49 (continued)

	Molecular weight		Elements being determined	Method
	M	log M		
	256.22	40 861	Zr^{IV}, F^-	Phot.
	126.11	10 075	Bi^{3+}, Sb^{3+} (in the form of MeR) B^{III}, Ta^V, Nb^V	Grav. Phot.
	210.21	32 265	Cu^{2+}, Pb^{2+}, Ag^+, Mn^{2+}, Ni^{2+}, Co^{2+}, Fe^{2+}, Cd^{2+}, Zn^{2+}, UO_2^{2+}, $FeOH^{2+}$, $AlOH^{2+}$, $CrOH^{2+}$ (in the form of MeR_n, where n is the valency of metal)	Grav.
	272.22	43 492	Be^{2+}, B^{III}, Mg^{2+}, Al^{3+}, Ga^{3+}	Phot.
	479.03	68 037	Sb^V, Zn^{2+}, Ga^{3+}, Tl^{3+}, W^{VI}, Cd^{2+}	Phot. (luminescence)

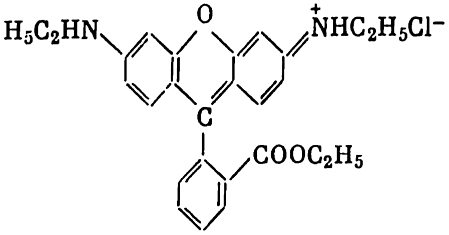
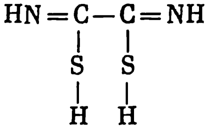
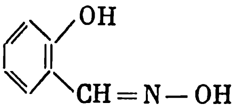
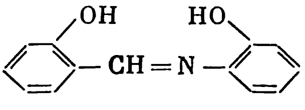
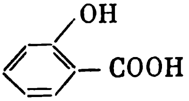
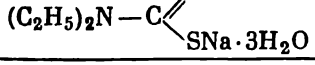
No.	Reagent	Synonymous names
76	Rhodamine 6G 	Ethyl ether of diethylamino-*o*-carboxyphenylxanthenyl chloride
77	Rubeanic acid  $HN{=}C(SH){-}C(SH){=}NH$	Dithioxamide
78	Salicylaldoxime 	—
79	Salicylal-*o*-aminophenol 	2, 2′-Dioxybenzylidenaniline
80	Salicylic acid 	*o*-Hydroxybenzoic acid
81	Sodium diethyldithiocarbomate  $(C_2H_5)_2N-C(=S)SNa\cdot 3H_2O$	—

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
450.97	65 415	Re^{VII}, In^{3+}, Tl^{+}	Phot. (luminescence)
120.20	07 990	Cu^{2+}, Co^{2+}, Ru^{IV}, Pd^{2+}, Ag^{+}	Phot.
137.14	13 716	Cu^{2+}, Bi^{3+}, Pb^{2+}, Pd^{2+} (in the form of MeR_2) Fe^{3+}	Grav. Phot.
213.24	32 887	Al^{3+} Mn^{2+}	Phot. (luminescence) Phot.
138.13	14 029	Fe^{3+}, Cu^{2+}	Phot.
225.34	35 284	Cu^{2+}, UO_2^{2+}, Ni^{2+}	Phot.

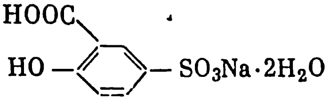
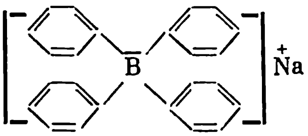
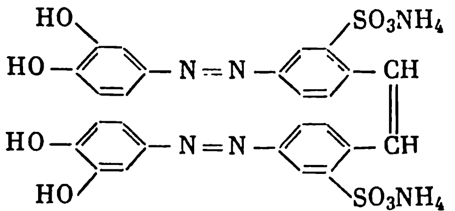
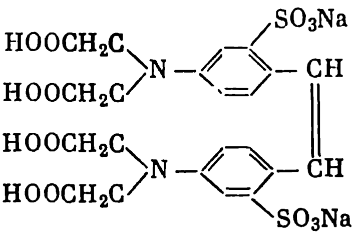
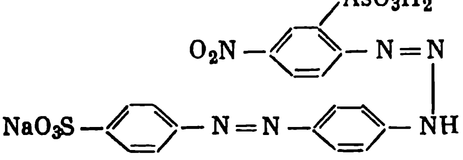
No.	Reagent	Synonymous names
82	Sodium sulphosalicylate 	—
83	Sodium tetraphenylborate 	Kalignost
84	Stilbazo 	Stilben-2-2′-disulphonic acid-4, 4′-bis-(azo-1″)-3″-4″-dioxybenzene, diammonium salt
85	Stilbexone 	4, 4′-Diaminostilben-(N, N, N′, N′-tetracarboxymethyl)-2-2′-disulphonic acid, disodium salt
86	Sulpharsasene 	Plumbone; 4″-nitrobenzene-(1″, 4)-diazoamino-(1-azo-1′)-benzene-2″-arsono-4′-sodium sulphonate

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
254.22	40 521	Fe^{3+}, Fe^{2+}	Phot.
342.24	53 433	K^+, Rb^+, Cs^+, Tl^+, NH_4^+	Grav., vol., phot.
646.66	81 068	Al^{3+}	Phot.
646.51	81 058	Fe^{3+}	Phot. (luminescence)
572.32	75 764	Pb^{2+}, Zn^{2+}, Cd^{2+}	Phot., vol.

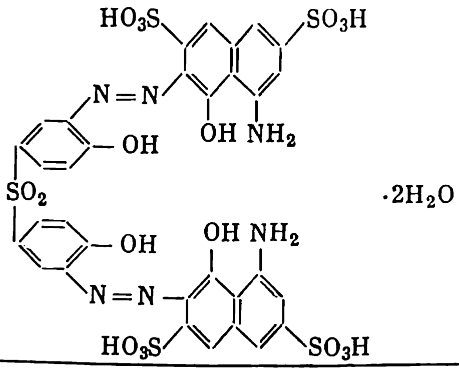
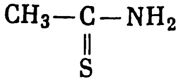
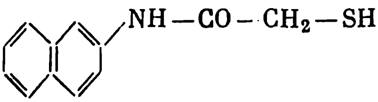
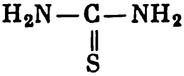
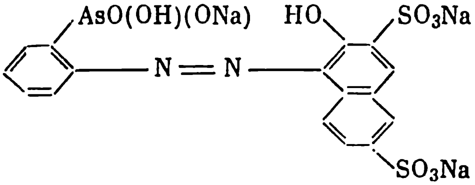
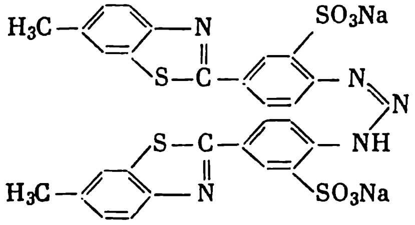
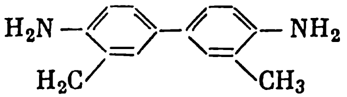
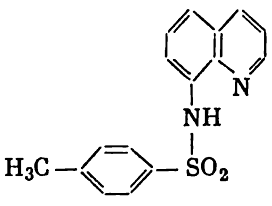
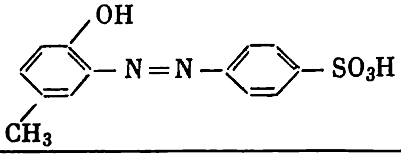
No.	Reagent	Synonymous names
87	Sulphonazo 	Sulphon-bis-[4-hydroxyphenyl-(3-azo-2')]-1'-hydroxy-8'-aminonaphthalene-3', 6'-disulphonic acid
88	Tannin $C_{76}H_{52}O_{46}$	—
89	Thioacetamide  $CH_3-\underset{\underset{S}{\Vert}}{C}-NH_2$	—
90	Thioglycolic acid $HSCH_2COOH$	—
91	Thionalide 	β-Aminonaphthalide of thioglycolic acid
92	Thiourea  $H_2N-\underset{\underset{S}{\Vert}}{C}-NH_2$	Thiocarbamide

Table 49 (continued)

Molecular weight		Elements being determined	Method
M	log M		
976.93	98 986	Sc^{3+}, V^{V}	Phot.
~1700	—	Be^{2+}, Al^{3+}, Ga^{3+}, Ge^{IV}, Mo^{VI}, Nb^{V}, Sn^{IV}, Ta^{V}, Ti^{IV}, UO_2^{2+}, W^{VI}, Zr^{IV}, Th^{IV} (precipitates are calcined to the oxides)	Grav.
75.13	87 581	Bi^{3+}, As^{3+}, Sb^{3+}, Cd^{2+}, Pb^{2+}, Sn^{2+}, Hg^{+}, MoO_2^{2+}, Cu^{2+}, Pb^{2+} Cu^{2+}	Grav. Phot.
92.120	96 435	Fe^{2+}, W^{VI}, Sn^{2+} (a reagent is added when tin is being determined by dithiol)	Phot.
217.29	33 704	Tl^{+}, As^{III}, Sb^{III}, Sn^{2+}, Ag^{+}, Au^{III}, Cu^{2+}, Hg^{2+}, Pd^{2+}, Bi^{3+}, Rh^{III}, Ru^{III}, Mn^{2+}, Pb^{2+}, Ni^{2+}, Co^{2+} (in the form of MeR_n, where n is the valency of metal)	Grav.
76.125	88 153	Bi^{3+}, Os^{VI}, Ru^{IV}, Re^{VII}, Te^{IV}	Phot.

No.	Reagent	Synonymous names
93	Thoron 	Benzene-2′-arsonic acid-(1′-azo-1)-2-hydroxynaphthalene-3, 6-disulphonic acid, trisodium salt; thorin, naphtharson, APANS
94	Titanium yellow 	Bis-4, 4′-[6-methylbenzothiazol-(1, 3)]-diazoaminobenzene-(2, 2′)-sodium disulphonate; mimosa; thiazo yellow
95	*o*-Tolidine 	—
96	8-Tosylaminoquinoline 	8-(*p*-Toluene sulphamido)-quinoline
97	Zirconon 	2-Hydroxy-5-methylazobenzene-4′-sulphonic acid

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* RE: rare-earth elements (lanthanoids, Y and Sc).

Table 49 (continued)

	Molecular weight		Elements being determined	Method
	M	$\log M$		
	598.29	77 691	Th^{IV}, F^-, U^{IV}, Zn^{2+}, Zr^{IV}, Ta^{V}, Nb^{V}, RE*, Bi^{3+}, Li^+, Be^{2+}	Phot.
	695.75	84 245	Mg^{2+}	Phot.
	212.30	32 695	OsO_4, RuO_4, Ag^{III}, V^{V}, halogens	Phot.
	298.35	47 473	Zn^{2+}, Cd^{2+}	Phot. (luminescence)
	292.32	46 586	Zr^{IV} (the precipitate is calcined to the oxide)	Grav.

Table 49 (continued)

B. In the Alphabetical Order of the Elements Being Determined

Element being determined	Reagent (No. according to Table A)	Method
Aluminium	26, 49, 73, 88	Grav.
	24, 49	Vol.
	1, 2, 3, 4, 7, 44, 48, 49, 57, 74, 79, 84	Phot.
Ammonium	83	Grav., vol. Phot.
Antimony	49, 72, 89, 91	Grav.
	49	Vol.
	15, 25, 49, 56, 75	Phot.
Arsenic	89, 91	Grav.
Barium	21, 24, 60	Vol.
Beryllium	88	Grav.
	1, 4, 7, 13, 27, 44, 74, 93	Phot.
Bismuth	26, 31, 49, 53, 67, 72, 78, 89, 91	Grav.
	24, 49	Vol.
	43, 49, 54, 92, 93	Phot.
Boron	22, 27, 72, 74	Phot.
Cadmium	5, 31, 49, 53, 59, 73, 89	Grav.
	24, 49, 86	Vol.
	16, 18, 19, 25, 36, 43, 49, 56 75, 86, 96	Phot.
Calcium	69	Grav.
	24	Vol.
	9, 58, 69	Phot.
Cesium	38, 83	Grav., phot.
	83	Vol.
Cerium	7, 8	Phot.
Chlorates and perchlorates	61	Grav.
Chromium (III)	49, 73	Grav.
	24, 49	Vol., phot.
Chromium (VI)	23, 36	Phot.
Cobalt	5, 31, 49, 62, 73, 91	Grav.
	24, 49	Vol.
	24, 35, 43, 49, 55, 62, 63, 64, 77	Phot.
Copper	5, 11, 24, 26, 29, 49, 53, 73, 78, 89, 91	Grav.
	24, 49	Vol.
	33, 35, 40, 41, 43, 49, 55, 62 70, 77, 80, 81, 89	Phot.
Cyanides	33	Vol.
Fluorine	2, 3, 4, 44, 71, 93	Phot.
Gallium	26, 49, 88	Grav.
	24, 49	Vol.
	3, 46, 48, 49, 50, 57, 74, 75	Phot.

Table 49 (continued)

Element being determined	Reagent (No. according to Table A)	Method
Germanium	68, 88	Phot.
Gold	53, 91	Grav.
	24	Vol.
	33, 95	Phot.
Hafnium	67	Grav.
	8	Phot.
Indium	49	Grav.
	24, 49	Vol.
	43, 49, 55, 76	Phot.
Iron (II)	73	Grav.
	24	Vol.
	10, 28, 35, 39, 65, 82, 90	Phot.
Iron (III)	26, 31, 49, 62, 73	Grav.
	24, 49	Vol.
	49, 62, 78, 80, 82, 85	Phot.
Lead	5, 29, 49, 53, 69, 73, 77, 78, 89	Grav.
	24, 47, 49, 86, 91	Vol.
	6, 36, 43, 49, 86, 89	Phot.
Lithium	93	Phot.
Magnesium	49, 69	Grav.
	24, 49	Vol.
	14, 49, 51, 52, 66, 74, 94	Phot.
Manganese	5, 49, 73, 91	Grav.
	24, 49	Vol.
	24, 49, 55, 79	Phot.
Mercury	5, 89, 91	Grav.
	24, 47	Vol.
	25, 33, 36, 37, 43, 56	Phot.
Molybdenum	49, 88, 89	Grav.
	49	Vol.
	42, 49, 55	Phot.
Neptunium	8	Phot.
Nickel	5, 12, 29, 35, 45, 49, 73, 91	Grav.
	24, 35, 49	Vol.
	35, 43, 45, 49, 81	Phot.
Niobium	26, 67, 88	Grav.
	7, 72, 93	Phot.
Nitrates	61	Grav.
	17	Phot.
Osmium	55, 92, 95	Phot.
Palladium	35, 45, 49, 78, 91	Grav.
	24, 35, 49	Vol.
	28, 33, 35, 45, 49, 55, 62, 77	Phot.
Platinum	45	Grav.
	33, 45	Phot.

Table 49 (continued)

Element being determined	Reagent (No. according to Table A)	Method
Plutonium	8	Phot.
Potassium	38, 83	Grav.
	83	Vol.
	38, 64, 83	Phot.
Protactinium	8	Phot.
RE*	24	Vol.
	7, 8, 93	Phot.
Rhenium	61	Grav.
	55, 56, 76, 92	Phot.
Rhodium	91	Grav.
Rubidium	38, 83	Grav.
	83	Vol.
Ruthenium	91	Grav.
	55, 91, 95	Phot.
Scandium	24	Vol.
	8, 87	Phot.
Selenium	30	Phot.
Silver	29, 53, 73, 91	Grav.
	24, 33	Vol.
	33, 37, 43, 77	Phot.
Strontium	69	Grav.
	24	Vol.
	58	Phot.
Sulphates	21, 60	Vol.
Tantalum	26, 67, 88	Grav.
	7, 34, 56, 68, 72, 93	Phot.
Thallium	53, 83, 91	Grav.
	24, 83	Vol.
	15, 25, 40, 43, 55, 56, 75, 76, 83	Phot.
Thorium	26, 67, 69, 88	Grav.
	24	Vol.
	2, 3, 7, 8, 48, 57, 93	Phot.
Tin	67, 88, 89, 91	Grav.
	24	Vol.
	42, 43, 68, 90	Phot.
Titanium	26, 31, 49, 88	Grav.
	24, 49	Vol.
	3, 7, 20, 23, 32, 40, 49	Phot.
Tungsten	49, 88	Grav., vol.
	42, 49, 75, 90	Phot.
Uranium	26, 73, 88	Grav.
	3, 7, 8, 81, 93	Phot.
Vanadium	26, 49	Grav.

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* RE: rare-earth elements (lanthanoids, Y and Sc).

Table 49 (continued)

Element being determined	Reagent (No. according to Table A)	Method
Vanadium	24, 49	Vol.
	7, 49, 55, 87, 95	Phot.
Wolfram	*see* Tungsten	
Zinc	5, 29, 49, 73	Grav.
	24, 49, 86	Vol.
	6, 15, 25, 43, 49, 56, 75, 86, 93, 96	Phot.
Zirconium	26, 49, 67, 88, 97	Grav.
	24, 49	Vol.
	2, 3, 7, 8, 44, 48, 49, 57, 68, 93	Phot.

Table 50

USSR Standard Sieves

Number of openings per cm	Number of openings per inch (mesh number)	Width of opening, mm	Diameter of wire, mm
125	325	0.044	0.036
106	270	0.053	0.041
93	230	0.062	0.046
79	200	0.074	0.053
66	170	0.088	0.063
56	140	0.105	0.074
47	120	0.125	0.086
40	100	0.149	0.102
34	80	0.177	0.119
29	70	0.21	0.140
24	60	0.25	0.162
20	50	0.30	0.188
18	45	0.35	0.22
15	40	0.42	0.25
13	35	0.50	0.29
11	30	0.59	0.33
9	25	0.71	0.37
8	20	0.84	0.42
7	18	1.00	0.48
6	16	1.19	0.54
5	14	1.41	0.61
4	12	1.68	0.69
3.5	10	2.00	0.76
3	8	2.38	0.84
2.7	7	2.83	0.92
2.3	6	3.36	1.02
2	5	4.00	1.12
1.7	4	4.76	1.27
1.4	3.5	5.66	1.45
1.2	3	6.72	1.65
1	2.5	8.00	1.85

Table 51

Half-Wave Potentials in Polarographic Analysis with a Dropping Mercury Electrode

Element being determined	Composition of the solution (background)	Valency change	Half-wave potential $E_{1/2}$, V
Al^{III}	0.5N $BaCl_2$ (the evolution of H_2 is possible)	3 → 0 (?)	—1.7
As^{III}	1M H_2SO_4 + 0.01% gelatin	3 → 0	—0.7
Bi^{III}	0.5N NaOH + 0.025% gelatin	3 → 5	—0.26
	1N H_2SO_4 + 0.01% gelatin	3 → 0	—0.04
	0.5M $KNaC_4H_4O_6$ + 0.01% gelatin		
	pH 4.5	3 → 0	—0.29
	pH 9	3 → 0	—0.70
	0.5M $NaKC_4H_4O_6$ + + 0.01N NaOH + 0.01% gelatin	3 → 0	—1.00
Br^{V}	Buffer solution, pH 1.0	5 → (—1)	—0.43
Ca^{II} and other alkaline-earth metals	Tetramethyl ammonium salt solutions	2 → 0	—2.22
Cd^{II}	0.1N HCl	2 → 0	—0.60
	6N HCl	2 → 0	—0.79
	1N NH_4Cl + 1N NH_4OH	2 → 0	—0.81
Ce^{IV}	0.1M ethylenediamine	4 → 3	—0.71
Co^{II}	0.25M KCl	2 → 0	—1.2
	1M KSCN	2 → 0	—1.03
	0.1M ethylenediamine	2 → 3	—0.456
Cr^{II}	0.7M HCl	2 → 3	—0.58
Cr^{III}	0.1N KCl	3 → 2 2 → 0	—0.81 —1.50
Cr^{VI}	1M KOH	6 → 3	—1.03
Cu^{I}	1M NH_4OH + 1M NH_4Cl	1 → 2 1 → 0	—0.25 —0.54

Table 51 (continued)

Element being determined	Composition of the solution (background)	Valency change	Half-wave potential $E_{1/2}$, V
Cu^{II}	$0.5M$ H_2SO_4 + 0.01% gelatin	$2 \rightarrow 0$	—0.00
	$0.5M$ $Na_2C_4H_4O_6$, pH 12	$2 \rightarrow 0$	—0.38
Fe^{II}	$1M$ $Na_2C_2O_4$	$3 \rightleftarrows 2$	—0.24
	$1M$ $Na_2C_2O_4$	$2 \rightleftarrows 3$	—0.24
	$1M$ $HClO_4$, pH 0-2	$2 \rightarrow 0$	—1.37
Fe^{III}	$0.5M$ $(NH_4)_2C_4H_4O_5$ + $1M$ NH_4OH + 0.005% gelatin	$3 \rightarrow 2$ $2 \rightarrow 0$	—0.98 —1.53
Ga^{III}	Salicylic acid, pH 2.8-3.2	$3 \rightarrow 0$	—0.85
	$1N$ NH_4OH + $1N$ NH_4Cl	$3 \rightarrow 0$	—1.58
Ge^{II}	$0.5M$ HCl	$2 \rightarrow 0$	—0.42
	$4M$ H_2SO_4	$2 \rightarrow 4$	—0.10
Ge^{IV}	$0.1M$ NH_4OH + $0.1M$ NH_4Cl	$4 \rightarrow 2$	—1.45
	$0.2M$ EDTA, pH 6.8	$4 \rightarrow 0$	—1.3
H^I	$0.1M$ KCl	$1 \rightarrow 0$	—1.58
H_2O_2	$0.1M$ Li_2SO_4	$(-1) \rightarrow (-2)$	—0.88
	$0.1M$ NaOH	$(-1) \rightarrow 0$	—0.17
I^V	$0.05M$ KCl	$5 \rightarrow (-1)$	—1.28
In^{III}	$HClO_4$, H_2SO_4, HNO_3	$3 \rightarrow 0$	—1.0
	$6N$ HCl	$3 \rightarrow 0$	—0.68
K^I and other alkaline metals	$0.1M$ tetramethyl ammonium	$1 \rightarrow 0$	—2.13
Mn^{II}	$0.5M$ NH_4OH + $0.5N$ NH_4Cl	$2 \rightarrow 0$	—1.54
	$2M$ NaOH + 5% $KNaC_4H_4O_6$	$2 \rightarrow 3$ $2 \rightarrow 0$	—0.4 —1.7
Mo^{VI}	$3M$ $HClO_4$	$6 \rightarrow 5$ $5 \rightarrow 3$	—0.14 —0.79
	$0.1M$ HCl	$6 \rightarrow 5$ $5 \rightarrow 3$	—0.29 —0.74
N^{III}	Buffer solution, pH 9	$3 \rightarrow 2$ $2 \rightarrow 1$ $1 \rightarrow (-1)$	—0.45 —0.70 —1.00

Table 51 (*continued*)

Element being determined	Composition of the solution (background)	Valency change	Half-wave potential $E_{1/2}$, V
N^{V}	0.1M LiCl	5 → (?)	−2.1
	0.1M $LaCl_3$; 0.1M $CeCl_3$	5 → (?)	−1.2
Nb^{V}	0.1M $H_2C_2O_4$, pH 1.2-5.5	5 → 4	−1.5
	0.06M HNO_3	5 → 3 (?)	−0.84
Ni^{II}	$HClO_4$, pH 0-2, 1N KCl	2 → 0	−1.1
	1M NH_4OH + 0.2M NH_4Cl + 0.005% gelatin	2 → 0	−1.06
O_2	Buffer solution, pH 1-10	0 → (−1) (−1) → (−2)	−0.05 −0.04
Os^{VI}	$Ca(OH)_2$ saturated	6 → 4 4 → 3	−1.41 −1.16
Pb^{II}	1M KCl	2 → 0	−0.431
	0.97M NaOH	2 → 0	−0.765
Pd^{II}	1M NH_4OH + 1M NH_4Cl + + 0.001% methyl red	2 → 0	−0.72
	2M NaOH or KOH	2 → 0	−1.41
Pt^{II}	0.5M KSCN + 0.05M ethylene diamine	2 → 0	−0.51
Re^{VII}	2M KCl	7 → (−1)	−1.43
	2M HCl	7 → 4 (?)	−0.45
Rh^{III}	1M NH_4OH + 1M NH_4Cl	3 → 1	−0.93
Sb^{III}	2M HCl	3 → 0 3 → 5	−0.22 −0.45
	1M NaOH	3 → 0	−1.15
Sb^{V}	2M HCl	5 → 0 (?)	−0.24
Se^{IV}	0.1M NH_4Cl + 0.003% gelatin	4 → (−2)	−1.50
Sn^{II}	1M H_2SO_4	2 → 0	−0.46
	1M HCl	2 → 4	−0.1
	1M NaOH + 0.01% gelatin	2 → 4 2 → 0	−0.73 −1.22
Sn^{IV}	1M HCl + 4M NH_4Cl + + 0.005% gelatin	4 → 2 2 → 0	−0.25 −0.52
	NaF	4 → 2	−1.2
Ta^{V}	0.86M HCl	5 → (?)	−1.16

Table 51 (continued)

Element being determined	Composition of the solution (background)	Valency change	Half-wave potential $E_{1/2}$, V
Te^{IV}	$0.1M$ NaOH + 0.003% gelatin	4 → (−2)	−1.22
	$0.1M$ $(NH_4)_2C_4H_4O_6$ + 0.003% gelatin, pH 9.0	4 → (0)?	−0.76
Te^{VI}	$0.1M$ NaOH + 0.03% gelatin	6 → (−2)	−1.66
	$0.1M$ NH_4Cl + NH_4OH + 0.0005% gelatin		
	pH 6.2	6 → (−2)	−1.17
	pH 9.2	6 → (−2)	−1.34
Ti^{III}	$0.1M$ HCl	3 → 4	−0.14
Ti^{IV}	$0.1M$ HCl	4 → 3	−0.81
	$0.2M$ $H_2C_4H_4O_6$	4 → 3	−0.38
	$0.4M$ $Na_2C_4H_4O_6$ + 0.005% gelatin, pH 11.8	4 → 3	−1.65
Ti^{I}	$1M$ KCl	1 → 0	−0.482
	$0.2M$ NaOH	1 → 0	−0.49
U^{IV}	$0.1M$ $NaClO_4$	4 → 3	−0.92
U^{V}	$0.1N$ KCl + HCl, pH 3	5 → 6	−0.18
U^{VI}	$0.5N$ HCl	6 → 5 5 → 3	−0.20 −0.92
V^{II}	$0.1M$ KCl	2 → 3	−0.50
	$Na_2B_4O_7$ saturated, pH 5.1	2 → 3 3 → 4 4 → 5	−0.55 −0.03 +0.13
V^{III}	$0.1M$ CO_3^{2-} + CO_2 saturated, pH 6.7	3 → 5	−0.06
V^{IV}	$0.1M$ H_2SO_4 + 0.005% gelatin	4 → 2	−0.85
	$1M$ NaOH + $0.08M$ Na_2SO_3 + $1M$ KCl	4 → 5	−0.39
V^{V}	$1M$ NH_4OH + $1M$ NH_4Cl + 0.005% gelatin	5 → 4 4 → 2	−0.97 −1.26
W^{VI}	$12M$ HCl	6 → 5 5 → 3	* −0.54

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* Reduced directly at the potential of mercury solution.

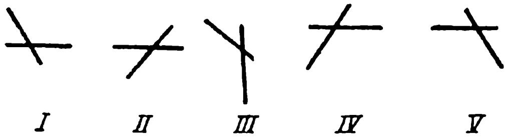
Table 51 (continued)

Element being determined	Composition of the solution (background)	Valency change	Half-wave potential, $E_{1/2}$, V
W^{VI}	$4M$ HCl	$5 \rightarrow 3$	-0.66
Zn^{II}	$1M$ KCl	$2 \rightarrow 0$	-1.02
	$1M$ NH_4OH + $0.2M$ NH_4Cl + 0.005% gelatin	$2 \rightarrow 0$	-1.33
	$1M$ NaOH	$2 \rightarrow 0$	-1.49
Zr^{IV}	$0.1M$ KCl, pH 3 (when $c_{Zr^{IV}} \simeq 1 \times 10^{-3}$)	$4 \rightarrow 0$	-1.65

Table 52

Amperometric Titration of Selected Substances (according

Abbreviations used: a — anodic (oxidizing) current; c — cathodic (re
Forms of titration curves



Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Ag^I	c	0	—0.25	HNO_3, KNO_3, CH_3COONa
	c	0	—0.25	HNO_3, KNO_3, CH_3COONa
	c	+0.40	+0.15	H_2SO_4
	c	+0.40	+0.15	H_2SO_4
	c	from 0 to +0.40	from —0.25 to +0.15	$NH_4OH + NH_4Cl$
As^{III}	a	+1.30	+1.05	HCl, H_2SO_4

to O. A. Songina)

ducing) current

Form of titration curve	Substance being titrated	Titrant	Remarks
I	Ag^{I}	I^-, Br^-, Cl^- and others which form sparingly soluble precipitates with Ag^{I}	—
II	Cl^-, Br^-, I^-, SCN^- and others which form sparingly soluble precipitates with Ag^{I}	Ag^{I}	—
I	Ag^{I}	I^- and others which form sparingly soluble precipitates with Ag^{I}	Titration can be conducted in the presence of Cu^{II}
II	Cl^- and others which form sparingly soluble precipitates with Ag^{I}	Ag^{I}	ditto
II	PO_4^{3-}	Ag^{I}	—
I	As^{III}	BrO_3^-	—

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Au^{III}	c	from 0 to +0.40	from −0.25 to +0.15	HCl, H_2SO_4, KNO_3, $NaNO_3$
	c	+0.40	+0.15	KNO_3, NH_4NO_3, H_2SO_4
Bi^{III}	c	+0.1	−0.15	$HClO_4$, pH 1.2 HNO_3, pH 1.5
Br_2	c	+0.45	+0.20	$NaHCO_3 + KBr$
	c	+0.40	+0.15	HCl, 2*N* H_2SO_4, 4*N* + Cl^-
Br^-	a	+1.30	+1.05	H_2SO_4, 2*N*
Ce^{IV}	c	+0.75	+0.50	H_2SO_4
	c	+0.45	+0.20	HCl

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
I	Au^{III}	$S_2O_3^{2-}$ and various organic compounds; for example, mercaptothiazole, hydroquinone, thiourea	Titration of Au^{III} with reducing agents is conducted more conveniently according to the current of their oxidation; for example, thiourea at the microelectrode potential equal to +0.8 V (microelectrode). In this case, the titration curve is of the II shape
I	Au^{III}	$Fe(CN)_6^{4-}$	—
II	PO_4^{3-}	Bi^{III}	—
II	As^{III}, NH_3	BrO^-, ClO^-	—
II	As^{III}, Sb^{III}	BrO_3^-	If the test solution contains Hg^{II}, Cu^{II}, Ag^{I} and others, titration is conducted at the microelectrode potential equal to +0.70 V
II	Tl^{III}	Br^-	—
II	Oxalate, V^{IV}, Fe^{II}, Tl^{I}	Ce^{IV}	If, under these conditions, the reducing agent yields an anodic current, then the titration curve has the reversible III shape
II	Sn^{II}	Ce^{IV}	

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Ce^{IV}	c	+1.00	+0.75	H_2SO_4
Ce^{III}	a	+1.60	+1.35	CH_3CO_2Na + ethanol
Cl_2	c	+0.70	+0.45	HCl
Cl^-	a	+1.50	+1.25	HCl
Cr^{VI}	c	+0.40 +0.40 +0.70 +0.90	+0.15 +0.15 +0.45 +0.65	HCl, $\leqslant 6N$ H_2SO_4, 4-6N H_2SO_4, 8-12N H_2SO_4, $>12N$
Cr^{II}	a	+0.65	+0:40	H_2SO_4
Cu^{II}	c	<+0.30	<+0.05	Indifferent electrolytes, diluted acids

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
III	Various organic compounds; for example, hydroquinone, methol, pyrocatechin, *p*-amidophenol and others	Ce^{IV}	Before the equivalence point—the organic-compound oxidation current; after the equivalence point—the Ce^{IV} reduction current
II	PO_4^{3-}	Ce^{III}	—
—	—	—	The value of the Cl_2 reduction current is used to determine chlorine in water
—	—	—	In a hydrochloride medium, the chloride oxidation current may inhibit other anodic processes
—	Various reducing agents, for example, Fe^{II}, Sb^{III}, As^{III}	$Cr_2O_7^{2-}$	The form of the titration curve depends on the reductant being titrated and the microelectrode potential
II	Mo^{VI}, W^{VI}	Cr^{II}	—
—	—	—	In amperometric titration, the Cu^{II} reduction current is not used, but it can hinder the determination of other substances

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Fe^{III}	c	−0.15	−0.40	$H_2SO_4 + (NH_4)_2SO_4$
	c	0	−0.25	HCl, ~1.2*N*
	c	0	−0.25	Depending on the substance being determined
Fe^{II}	a	+1.25	+1.00	H_2SO_4
	a	+1.10	+0.85	H_2SO_4, HCl
$Fe(CN)_6^{3-}$	c	+0.05	−0.20	$NH_4OH + NH_4Cl$
	c	+0.20	−0.05	NaOH
$Fe(CN)_6^{4-}$	a	from +0.70 to 1.00	from +0.45 to +0.75	—

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
II	Ti^{III}	Fe^{III}	—
I	Fe^{III}	Ascorbic acid	—
V	Zr^{IV}, Al^{III}, Be^{II}	F^-	Titration is conducted in the presence of Fe^{III} (indicator method)
II	Mn^{VII}, Cr^{VI}, V^{V}, Ce^{IV}	Fe^{II}	If, under these conditions, the oxidizing agent produces a cathodic current, then the titration curve has the III shape
I	Fe^{II}	MnO_4^-, $Cr_2O_7^{2-}$, VO_3^-, Ce^{IV}	Ditto
II	Co^{II}	$Fe(CN)_6^{3-}$	It is possible to titrate $Fe(CN)_6^{3-}$ with a standard Co^{II} solution, then the titration curve has the I form
II	Tl^{I}	$Fe(CN)_6^{3-}$	Titration with hexacyanoferrate is conducted in the presence of a catalyst: OsO_4
—	Zn^{II}, Pb^{II}, Cd^{II}, Ca^{II}, Cu^{II}, Mn^{II}, Zn^{III}, Ag^{I} and others which form sparingly soluble precipitates. Au^{III}: by reduction reaction	$Fe(CN)_6^{4-}$	The microelectrode potential, the background composition and, consequently, the form of the titration curve depend on the substance being determined

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Hg^{II}	c	+0.40	+0.15	$NaNO_3$, NH_4NO_3, H_2SO_4
	c	+0.40	+0.15	$NaNO_3$, NH_4NO_3, H_2SO_4
Hg^{I}	c	+0.40	+0.15	$NaNO_3$, NH_4NO_3
		Beginning of reduction		
H_2O	c	-0.70	-0.95	Alkaline medium
		-0.40	-0.65	Neutral medium
		0	-0.25	Acidic medium
	a	*Beginning of oxidation*		
		+0.80	+0.55	Alkaline medium
		+1.20	+0.95	Neutral medium
		+1.50	+1.25	Acidic medium
I_2	c	+0.20	-0.05	HCl, $\geqslant 9N$
	c	0	-0.25	CH_3CO_2Na
	c	+0.45	+0.20	Seignette salt + + $NaHCO_3$
	c	+0.40	+0.15	HCl, $2N$; H_2SO_4, $2N$ + + KCl
I^-	a	+1.00	+0.75	H_2SO_4, pH 1-2
	a	+1.00	+0.75	KNO_3, NH_4NO_3
	a	+1.00	+0.75	HCl $\geqslant 6N$
Ir^{IV}	c	+0.70	+0.45	HCl

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
I	Hg^{II}	I^-, Cl^-	—
II	Cl^-	Hg^{II}	—
II	Pyrophosphate, Mo^{VI}, W^{VI}	Hg^{I}	—
—	—	—	Water-reduction current limits the cathodic region of electrode reaction
—	—	—	Water-oxidation current limits the anodic region of electrode reaction
IV	As^{V}, Se^{IV}	I^-	—
I	I_2	$S_2O_3^{2-}$	This reaction is used to determine Cu^{II}, Fe^{III}, As^{V} after adding an excess of I^- to the test solution
II	Sn^{II}, As^{III}, Sb^{III}	I_2	—
II	Sb^{III}, Tl^{I}	IO_3^-	—
II	Ag^{I}, Hg^{II}, Pd^{II}	I^-	—
II	Tl^{I}	I^-	—
II	Se^{IV}	I^-	—
I	Ir^{IV}	Ascorbic acid, hydroquinone	—

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Mn^{VII}	c	+0.80	+0.55	$H_2SO_4 \leqslant 8N$
	c	+0.75	+0.50	HCl, $1N$
	c	+0.40	+0.15	$CH_3CO_2Na + ZnO$
	c	+0.40	+0.15	$K_4P_2O_7$, pH 6-7
	c	+0.40	+0.15	NaOH, $1N$
Mn^{III}	c	+0.90	+0.65	$H_2SO_4 \geqslant 9N$
	c	+0.90	+0.65	$H_3PO_4 \geqslant 10N$
Mn^{II}	a	+1.20	+0.95	Acid, neutral, CH_3CO_2Na

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
—	Various reducing agents, for example, oxalate, ferrocyanide, V^{IV}, Fe^{II}, As^{III}, Sb^{III}, Sn^{II}	MnO_4^-	The form of the titration curve depends on the substance being titrated
II	Tl^I	MnO_4^-	—
II	Mn^{II}	MnO_4^-	—
II	Mn^{II}	MnO_4^-	—
II	Te^{IV}	MnO_4^-	—
I	Mn^{III}	$H_2C_2O_4$	This reaction is used to determine PrO_2 after adding an excess of Mn^{II} to the test solution
I	Mn^{III}	Fe^{II}	It is possible to titrate Mn^{III} according to the Fe^{II} oxidation current when the microelectrode potential is +1.3 V. In this case, the titration curve has the II form
—	—	—	In amperometric titration, the Mn^{II} oxidation current is not used, but it can hinder the determination of other substances

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
NO_2^-	c	from +0.40 to +1.00 depending on HNO_3 concentration	from +0.15 to +0.75	
NO_2^-	a	+1.30	+1.05	H_2SO_4, 0.05*N*
O_2	c	*Beginning of reduction* +0.10 +0.40 +0.80	 −0.15 +0.15 +0.55	 Alkaline medium Neutral medium Acid medium
Pb^{II}	c	−0.60	−0.85	CH_3CO_2Na, $CH_3CO_2NH_4$

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
—	—	—	In amperometric titration, the NO_2^- reduction current is not used, but it can hinder the determination of other substances if the HNO_3 concentration used as a background is $\geqslant 5N$
I	NO_2^-	Strong oxidizers, for example, MnO_4^-, Ce^{IV} sulphanilic acid	For the amperometric titration of NO_2^-, against the background of ammonium citrate (pH 4-4.5) it is also possible to use chloroamine T as a titrant with its reduction current, at the microelectrode potential equal to +0.3 V
—	—	—	The O_2 reduction current is used in the polarographic determination of dissolved oxygen. In amperometric titration, the O_2 reduction current hinders the determination of other substances
I	Pb^{II}	$Cr_2O_7^{2-}$, MoO_4^{2-}, WO_4^{2-}	—

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Pb^{II}	c	+1.80	+1.55	$CH_3CO_2NH_4$ or CH_3CO_2Na, 0.5*N*
Sn^{II}	a	—0.20	—0.45	Alkaline solution of complexone III
Te^{IV}	c	+0.60	+0.35	H_2SO_4, 6*N*
Ti^{III}	a a a	+0.75 +1.00 +1.00	+0.50 +0.75 +0.75	$H_2SO_4 + (NH_4)_2SO_4$ H_2SO_4, 10*N* H_2SO_4, 1*N* + $H_4P_2O_7$
Tl^{III}	c	+0.50	+0.25	KNO_3, CH_3CO_2Na and others

Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
II	SO_4^{2-}	Pb^{II}	The titrant is the solution of lead acetate salt containing 4-5% of acetic acid
III	Sn^{II}	Hg^{II}	The titrant is the solution of mercuric chloride salt. Beyond the equivalence point—the Hg^{II} reduction current
	—	—	In amperometric titration, the Te^{IV} reduction current is not measured, but it can hinder the determination of other substances
I II II	Ti^{III} V^{V}, Cr^{VI} U^{VI}	$Cr_2O_7^{2-}$ Ti^{III} Ti^{III}	— — —
I	Tl^{III}	Various reducing agents, for example, thiourea	Amperometric titration of Tl^{III} with thiourea is more convenient to conduct according to the current of the oxidation of the latter at the microelectrode potential equal to +0.80 V. In this case, the titration curve has the II form

Ion or molecule which produces diffusion current	Nature of electrode reaction	Potential of the platinum indicator microelectrode relative to the reference electrode		Composition of background solution
		microelectrode, V	saturated calomel electrode, V	
Tl^{I}	c a	—0.60 +1.40	—0.85 +1.15	CH_3CO_2Na KNO_3, NH_4NO_3, H_2SO_4
U^{III}	a	+0.20	—0.05	H_2SO_4
V^{V}	c	+0.50	+0.25	H_2SO_4, 12-16*N*
	c	+1.00	+0.75	H_2SO_4, 18-24*N*
V^{IV}	a	+0.85	+0.60	$CH_3CO_2H + CH_3CO_2Na$, pH 4
V^{II}	a a	+0.85 +0.45	+0.60 +0.20	$H_2SO_4 + H_3PO_4$ H_2SO_4

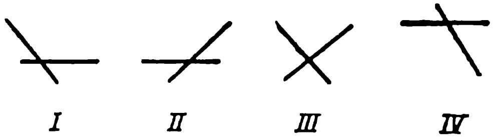
Table 52 (continued)

Form of titration curve	Substance being titrated	Titrant	Remarks
I	Tl^{I}	I^-	—
	—	—	In amperometric titration, the Tl^- oxidation current is not used, but it can hinder the determination of other substances
III	U^{III}	Fe^{III}	Beyond the equivalence point—the Fe^{III} reduction current
II	Various reducing agents, for example, Fe^{II}	VO_3^-	—
III	V^{V}	Fe^{II}	Beyond the equivalence point—the Fe^{II} oxidation current
II	Complexone III	VO^{2+}	This reaction is used to determine Al^{III}, Zr^{IV}, Th^{IV} and other substances after adding an excess of complexone III to the test solution
II	Mo^{VI}, V^{IV}	V^{II}	—
II	Ti^{IV}, V^{V}	V^{II}	—

Table 53

Conditions of Amperometric Titration with Two Polarized

Forms of titration curves



In amperometric titration with two polarized electrodes, the latter must be in the titrate simultaneously and must have a sufficiently large surface (this being the difference in respect of classical amperometric titration with a microelectrode). Voltage is applied to the electrodes with the aid of a voltage divider from an external source of direct current with a small output voltage (~2-4 V). The amount of voltage applied to the electrodes is controlled (without trying to achieve great accuracy) by a d.c. voltmeter which is connected to the circuit parallel to the electrodes.

The fourth column of the table gives approximate voltages applied to the electrodes, at which the latter are depolarized before the equivalence point or after it, or in the entire process of titration.

The fifth column gives the oxidation-reduction systems whose components provide an indicator current, which arises due to the

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator	
				before the equivalence point	
Ag^I	Cl^-, Br^-, I^-	Hg	from 1 to 10	$Ag^I/Hg\downarrow$	
Al^{III}	F^-	Pt	100	—	
As^{III}	BrO_3^-	Pt	50	—	
	$Fe(CN)_6^{3-}$	Pt	200	—	

Indicator Electrodes (according to O. A. Songina)

depolarization of electrodes. The dashes in this column indicate the absence of the indicator current either before or after the equivalence point at a given voltage applied to the indicator electrodes. This occurs when, in the process of titration, the components of an oxidation-reduction system either being formed or present in the titrate cannot, at a given voltage, be oxidized and reduced at the electrodes, or when one of the conjugated forms of the redox pair is absent.

In some cases, depending on the composition and amount of voltage applied to the electrodes, an oxidized form of one and a reduced form of another redox system can participate in electrochemical reactions, thus providing an indicator current before and (or) after the equivalence point.

In the sixth column, Roman numerals indicate the forms of titration curves near the equivalence point.

which induce the current	Form of titration curves near the equivalence point	Remarks
after the equivalence point		
—	I	As electrodes, ground mercury is used. Before the equivalence point is reached, the electrode material—Hg↓ (anode)—is oxidized, and Ag^{I} is reduced at the cathode
—	IV	Titration is conducted in the presence of the redox pair Fe^{III}/Fe^{II}
Br_2/Br^-	II	Titration is conducted in the presence of Br^-
$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	II	Titration is conducted in the presence of an OsO_4 catalyst

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator	
				before the equivalence point	
Au^{III}	Ascorbic acid	Pt	100	Au^{III}/Cl^-	
Ba^{II}	F^-	Pt	100	—	
Br^-	Ag^I	Ag	10	—	
	Hg^I	Hg	from 1 to 10	—	
Ca^{II}	F^-	Pt	100	—	
	Complexone III	Cathode: Pt anode: amalgamated Ag	130	—	
	$Fe(CN)_6^{4-}$	Pt	400	—	
Cd^{II}	$Fe(CN)_6^{4-}$	Pt	200	—	
Ce^{IV}	Ascorbic acid, oxalic acid	Pt	200	Ce^{IV}/Ce^{III}	
	Fe^{II}	Pt	200	Ce^{IV}/Ce^{III}	

Table 53 (continued)

which induce the current	Form of titration curves near the equivalence point	Remarks
after the equivalence point		
—	I	Titration is conducted in a hydrochloric acid medium. Before the equivalence point is reached Au^{III} is reduced at the cathode, and Cl^- is oxidized at the anode
—	IV	Titration is conducted in the presence of the redox pair Fe^{III}/Fe^{II}
$Ag^{I}/Ag\downarrow$	II	Beyond the equivalence point, the electrode material—$Ag\downarrow$ (anode)—is oxidized
$Hg^{I}/Hg\downarrow$	II	As electrodes, ground mercury is used. Beyond the equivalence point, the electrode material—$Hg\downarrow$ (anode)—is oxidized
—	IV	Titration is conducted in the presence of the redox pair Fe^{III}/Fe^{II}
—	IV	Titration is conducted in an alkaline medium in the presence of Hg^{II}
$H^+/Fe(CN)_6^{4-}$	II	As a titrant, $(NH_4)_4Fe(CN)_6$ is used. Beyond the equivalence point, H^+ is reduced at the cathode and $Fe(CN)_6^{4-}$ is oxidized at the anode
$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	II	Titration is conducted in the presence of $Fe(CN)_6^{3-}$
—	I	—
Fe^{III}/Fe^{II}	III	—

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator	
				before the equivalence point	
Ce^{IV}	N-Benzoylphenylhydroxylamine	Pt	800	Ce^{IV}/H_2O or background	
	Cupferron	Pt	1000	Ce^{IV}/Ce^{III}	
Cl^-	Ag^I	Ag	from 1 to 10	—	
	Hg^I	Hg	from 1 to 10	—	
Co^{III}	Ascorbic acid	Pt	100	The mechanism	
Co^{II}	Ce^{IV}, $Cr_2O_7^{2-}$, VO_3^-	Pt	100	The mechanism	
	Fe^{III}	Pt	1000	The mechanism	
Cr^{IV}	Fe^{II}	Pt	100	—	
	Fe^{II}	Pt	150	—	
Cu^{II}	Complexone III	Cu	20	$Cu^{II}/Cu\downarrow$	

Table 53 (continued)

which induce the current	Form of titration curves near the equivalence point	Remarks
after the equivalence point		
—	I	Before the equivalence point is reached, Ce^{IV} is reduced at the cathode and, at the anode, water or the background electrolyte is oxidized, for example Cl^-, if titration is conducted in a sulphuric acid medium or in the presence of chloride
H^+/cupferron	III	Before the equivalence point is reached, cupferron reduces Ce^{IV}. Beyond the equivalence point, H^+ is reduced at the cathode, and cupferron is oxidized at the anode
$Ag^I/Ag\downarrow$	II	Beyond the equivalence point, the electrode material—$Ag\downarrow$ (anode)—is oxidized
$Hg^I/Hg\downarrow$	II	As electrodes, ground mercury is used. Beyond the equivalence point, the electrode material—$Hg\downarrow$ (anode)—is oxidized
is not established	—	The titrate is the cobaltic carbonate complex solution
is not established	—	Titration is conducted in the presence of complexone III
is not established	—	Titration is conducted in the presence of phenanthroline
Fe^{III}/Fe^{II}	II	—
Fe^{III}/Fe^{II}	II	Titration is conducted with a ferrous perchlorate solution in glacial acetic acid
—	I	Before the equivalence point is reached, the electrode material—$Cu\downarrow$ (anode)—is oxidized, and Cu^{II} is reduced at the cathode

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator	
				before the equivalence point	
Cu^{II}	Complexone III	Pt, graphite	From 1000 to 1400	—	
Fe^{III}	Complexone III	Pt, graphite	from 1000 to 1400	—	
	Ascorbic acid	Pt	100	Fe^{III}/Fe^{II}	
Fe^{II}	Ce^{IV}, MnO_4^-, $Cr_2O_7^{2-}$	Pt	100	Fe^{III}/Fe^{II}	
	CrO_3	Pt	150	Fe^{III}/Fe^{II}	
$Fe(CN)_6^{3-}$	AsO_2^-	Pt	150	$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	
$Fe(CN)_6^{4-}$	MnO_4^-	Pt	150	$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	
	Ce^{IV}	Pt	150	$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	
	Zn^{II}	Pt	150	$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	
Ga^{III}	$Fe(CN)_6^{4-}$	Pt	200	—	

Table 53 (continued)

which induce the current		Form of titration curves near the equivalence point	Remarks
	after the equivalence point		
	H^{++} cupric complexonate/complexone III	II	Beyond the equivalence point, H^+ and cupric complexonate are reduced simultaneously, and complexone III is oxidized at the anode
	$H^+ +$ ferric complexonate/complexone III	II	Beyond the equivalence point, H^+ and ferric complexonate are reduced simultaneously, and complexone III is oxidized at the anode
	—	I	—
	—	I	—
	—	I	Titration is conducted in glacial acetic acid with a ferrous perchlorate solution
	—	I	Titration is conducted in the presence of an OsO_4 catalyst. This reaction can be used to indirectly determine Hg^{I}, Co^{II}, Sn^{II}, Sb^{III}, As^{III}, Se^{IV} and others by the titration of the excess of $Fe(CN)_6^{3-}$
	—	I	—
	Ce^{IV}/Ce^{III}	III	—
	—	I	Titration is conducted in the presence of $Fe(CN)_6^{3-}$. As a titrant, use can also be made of other cations which form sparingly soluble precipitates with ferrocyanide, hexacyanoferrate (II); for example, Cd^{II}
	$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	II	Titration is conducted in the presence of $Fe(CN)_6^{3-}$

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator	
				before the equivalence point	
H_2O	Fisher's reagent	Pt	30	—	
Hg^{II}	Complexone III	Hg	from 1 to 10	$Hg^{II}/Hg\downarrow$	
	I^-	Pt	30	—	
Hg^{I}	CN^-, SCN^-, Cl^-, Br^-, I^-	Hg	from 1 to 10	$Hg^{I}/Hg\downarrow$	
In^{III}	$Fe(CN)_6^{4-}$	Pt	200	—	
I_2	AsO_2^-, $S_2O_3^{2-}$, $N_2H_4 \times HCl$	Hg	30	I_2/I^-	
I^-	Ag^{I}	Ag	10	—	
	Ag^{I}	Pt	30	I_2/I^-	
K^+	Ag^+	Ag	25	—	
La^{III}	$Fe(CN)_6^{4-}$	Pt	400	—	

Table 53 (continued)

which induce the current	Form of titration curves near the equivalence point	Remarks
after the equivalence point		
I_2/I^-	II	This reaction is used to determine water in organic and inorganic materials
—	I	As electrodes, ground mercury is used. Before the equivalence point is reached, the electrode material—$Hg\downarrow$ (anode)—is oxidized
I_2/I^-	II	Titration is conducted in the presence of $Cr_2O_7^{2-}$ or I_2
—	I	As electrodes, ground mercury is used. Before the equivalence point is reached, the electrode material—$Hg\downarrow$ (anode)—is oxidized
$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	II	Titration is conducted in the presence of $Fe(CN)_6^{3-}$
—	I	This reaction can be used to indirectly determine Cl_2, H_2O_2, O_2, Cu^{II}, Tl^{III}, Se^{IV} and others by the titration of I_2, which separates after adding an excess of iodide
$Ag^I/Ag\downarrow$	II	Beyond the equivalence point, the electrode material—$Ag\downarrow$ (anode)—is oxidized
—	I	Titration is conducted in the presence of I_2
$Ag^I/Ag\downarrow$	I	Titration of potassium tetraphenylborate is conducted in acetone. Beyond the equivalence point, the electrode material—$Ag\downarrow$ (anode)—is oxidized
$H^+/Fe(CN)_6^{4-}$	II	Beyond the equivalence point, H^+ is reduced at the cathode

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator	
				before the equivalence point	
Mg^{II}	BrO_3^-	Pt	50	—	
	Complexone III	Cathode: Pt, anode: amalgamated Ag	210	—	
MnO_4^-	Fe^{II}	Pt	100	—	
	Fe^{II}	Pt	150		
Mn^{II}	MnO_4^-	Cathode: Pt, anode: Ag	Without the application of voltage		
Mo^{VI}	Pb^{II}	Pt	1300	—	
NO_3^-	Fe^{II}	Pt	100	—	
Ni^{II}	Dimethylglyoxime	Cathode: amalgamated Ag, anode: Pt	1500	Ni^{II}/OH^-	
	I_2	Pt	30	—	
SO_3^{2-}	ICl	Pt	800	—	
$S_2O_3^{2-}$	I_2, IO_3^-	Pt	from 30 to 100	—	

Table 53 (continued)

which induce the current		Form of titration curves near the equivalence point	Remarks
	after the equivalence point		
	Br_2/Br^-	II	The titration of magnesium hydroxyquinolate is conducted in the presence of Br^-
	Mercuric complexonate/$Hg\downarrow$	IV	Titration is conducted in an ammonia buffer solution in the presence of Hg^{II}
	Fe^{III}/Fe^{II}	II	—
	Fe^{III}/Fe^{II}	II	Titration is conducted with ferrous perchlorate solution in glacial acetic acid
	$MnO_4^-/Ag\downarrow$	II	Beyond the equivalence point, the electrode material—$Ag\downarrow$ (anode)—is oxidized, and MnO_4^- is reduced at the cathode
	H^+/Pb^{II}	II	Beyond the equivalence point, H^+ is reduced at the cathode, and Pb^{II} is oxidized at the anode
	Fe^{III}/Fe^{II}	II	—
	—	I	Before the equivalence point is reached, Ni^{II} is reduced at the cathode, and OH^- is oxidized at the anode (alkaline medium)
	I_2/I^-	II	Titration is conducted in the presence of dimethylglyoxime
	I_2/I^-	II	Titration is conducted in glacial acetic acid
	I_2/I^-	II	—

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator
				before the equivalence point
SCN^-	Ce^{IV}	Pt	200	—
Sb^{III}	BrO_3^-	Pt	from 50 to 100	—
Sn^{II}	I_2	Pt	30	—
Th^{IV}	Complexone III	Pt	100	—
Ti^{III}	Ce^{IV}	Pt	100	—
Tl^{I}	Complexone III	Graphite, Pt	from 1000 to 1400	—
	$Fe(CN)_6^{4-}$	Pt	400	—
	Ce^{IV}	Pt	100	—
U^{IV}	VO_3^-	Pt	from 200 to 300	—
	Fe^{III}	Pt	100	—
	Complexone III	Pt	500	H^+/U^{IV}
V^{V}	Fe^{II}	Pt	100	—

Table 53 (continued)

which induce the current	Form of titration curves near the equivalence point	Remarks
after the equivalence point		
Ce^{IV}/Ce^{III}	II	Titration is conducted in the presence of pyridine and an ICl catalyst. This reaction can be used to indirectly determine Cu^{II}, Co^{II}, Cd^{II}, Ni^{II} by the titration of an excess of SCN^-
Br_2/Br^-	II	—
I_2/I^-	II	—
—	IV	Titration is conducted in the presence of the Fe^{III}/Fe^{II} redox pair
Ce^{IV}/Ce^{III}	II	—
H^+ + thallic complexonate/complexone III	II	Beyond the equivalence point, H^+ and thallic complexonate are reduced simultaneously at the cathode, and complexone III is oxidized at the anode
$H^+/Fe(CN)_6^{4-}$	II	Beyond the equivalence point, H^+ is reduced at the cathode, and $Fe(CN)_6^{4-}$ is oxidized at the anode
Ce^{IV}/Ce^{III}	II	
V^V/V^{IV}	II	
Fe^{III}/Fe^{II}	II	
—	I	Before the equivalence point is reached, H^+ is reduced at the cathode, and U^{IV} is oxidized at the anode
Fe^{III}/Fe^{II}	II	

Substance being determined	Titrant	Electrode material	Voltage being applied, mV	Electrode reactions indicator
				before the equivalence point
W^{VI}	Pb^{II}	Pt	1500	—
Y^{III}	Cupferron	Pt^{II}	from 1000 to 1200	—
Zn^{II}	$Fe(CN)_6^{4-}$	Pt	200	—

Table 53 (continued)

which induce the current		Form of titration curves near the equivalence point	Remarks
	after the equivalence point		
	H^+/Pb^{II}	II	Beyond the equivalence point, H^+ is reduced at the cathode, and Pb^{II} is oxidized at the anode
	H^+/cupferron	II	Beyond the equivalence point, H^+ is reduced at the cathode, and cupferron is oxidized at the anode
	$Fe(CN)_6^{3-}/Fe(CN)_6^{4-}$	II	Titration is conducted in the presence of $Fe(CN)_6^{3-}$

Table 54

Overvoltage of Hydrogen and Oxygen at Various Electrodes

(at room temperature)

The dependence of the hydrogen overvoltage η_{H_2} on current density is expressed by the equation

$$\eta_{H_2} = 0.116 \log i + k$$

where k is a constant which depends on the nature of the electrode. With a rise in temperature, the value of overvoltage decreases by 3 mV/°C. In an alkaline medium, hydrogen overvoltage is as a rule somewhat greater (by 0.1-0.3 V) than in an acidic medium. The overvoltage of oxygen in an alkaline medium is approximately one volt greater than in an acidic medium. The overvoltage of electroseparation of metals is considerably less than that of gases.

Electrode	Composition of the solution	Current density, A/cm²				
		0.00005 and less	0.0001	0.001	0.01	0.1
		overvoltage, V				
		Hydrogen				
Palladium	2N H_2SO_4	−0.26	—	—	—	—
Platinum (platinized)	ditto	0.000	—	—	0.03	0.04
Platinum (smooth)	2N H_2SO_4	0.008	—	—	0.07	0.29
	5N H_2SO_4	—	0.04	0.10	0.22	—
Gold	2N H_2SO_4	0.017	—	—	0.39	0.59
	5N H_2SO_4	—	0.33	0.44	0.55	—
Cobalt	2N H_2SO_4	0.067	—	—	—	—
Silver	2N H_2SO_4	0.97	—	—	—	—
	5N H_2SO_4	—	0.45	0.57	0.69	—
Vanadium	2N H_2SO_4	0.135	—	—	—	—
Nickel	2N H_2SO_4	0.138	—	—	—	—
	0.15N HCl	—	0.18	0.28	—	—
	0.4N NaOH	—	0.18	0.29	—	—
Tungsten	2N H_2SO_4	0.157	—	—	—	—
Molybdenum	2N H_2SO_4	0.168	—	—	—	—
Iron	2N H_2SO_4	0.175	—	—	0.56	0.82
	1N HCl	—	—	0.33	0.46	—
	5N NaOH	—	0.32	—	—	—
Chromium	2N H_2SO_4	0.182	—	—	—	—
Copper	1N H_2SO_4	—	0.83	0.94	1.04	—
	2N H_2SO_4	0.190	—	—	0.58	0.85

Table 54 (continued)

Electrode	Composition of the solution	Current density, A/cm²				
		0.00005 and less	0.0001	0.001	0.01	0.1
		overvoltage, V				
Antimony	2*N* H_2SO_4	0.233	—	—	—	—
Titanium	2*N* H_2SO_4	0.236	—	—	—	—
Aluminium	2*N* H_2SO_4	0.296	—	—	—	—
Carbon	2*N* H_2SO_4	0.335	0.77	0.88	1.0	—
Arsenic	2*N* H_2SO_4	0.369	—	—	—	—
Bismuth	2*N* H_2SO_4	0.388	—	—	—	—
Cadmium	1*N* H_2SO_4	—	—	0.98	1.13	—
	2*N* H_2SO_4	0.392	—	—	—	—
Tin	2*N* H_2SO_4	0.401	—	—	1.08	1.22
Lead	2*N* H_2SO_4	0.402	0.98	1.1	1.21	—
Zinc	2*N* H_2SO_4	0.482	—	—	0.75	1.06
Mercury	1*N* H_2SO_4	—	0.93	1.04	1.16	—
	2*N* H_2SO_4	0.570	—	—	1.04	1.07
		Oxygen				
Platinum (smooth)	In acidic medium	—	—	—	~0.4*	—
	0.2*N* H_2SO_4	—	0.67	0.78	—	—
From lead dioxide	8*N* H_2SO_4	—	0.97	1.08	1.19	—
Iron	2*N* NaOH	—	0.44	0.48	0.52	—

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* 0.023 A/cm².

Table 55

Potentials of Electrode Decomposition of 1*N* Solutions of Selected Compounds

Compound	Decomposition potential, V	Compound	Decomposition potential, V
Salts			
$AgNO_3$	0.70	HBr	0.94
$CuSO_4$	1.49	$(COOH)_2$	0.95
$Pb(NO_3)_2$	1.52	HCl	1.31
$CoCl_2$	1.78	$HClO_4$	1.65
$ZnBr_2$	1.80	H_2SO_4	1.67
$NiCl_2$	1.85	HNO_3	1.69
$CdCl_2$	1.88	$CH_2(COOH)_2$	1.69
$CoSO_4$	1.92	H_3PO_4	1.70
$Cd(NO_3)_2$	1.98	$CH_2ClCOOH$	1.72
$CdSO_4$	2.03	*Bases*	
$NiSO_4$	2.09		
$ZnSO_4$	2.35	KOH	1.67
Acids		NaOH	1.69
		NH_4OH	1.74
HI	0.52		

Table 56

Flame Photometry

Recommended wavelengths of the spectral lines and the molecular-band maxima for determining the elements with the aid of a spectrophotometer having glass optics and with the use of an air-acetylene flame
(the wavelengths of molecular-band maxima are italicized)

Element	Wavelength, nm	Element	Wavelength, nm
Barium	*870.0*	Lithium	670.8
Boron	*545.0-548.0*	Magnesium	*384.0*
Calcium	422.7	Manganese	403.1-403.4
Calcium	*622.0*	Phosphorus	548.0
Cesium	852.1	Potassium	766.5-769.9
Chromium	425.4	Rubidium	794.8
Europium	459.4	Sodium	589.0-589.6
Gallium	417.2	Strontium	460.7
Indium	451.1	Thallium	535.1
Iron	386.0	Ytterbium	398.8
Lanthanum	*438.0*	Yttrium	*613.0-616.6*
Lanthanum	*794.0*		

Table 57

British and American Weights and Measures in Comparison with the Metric System of Measurement

Name	Metric equivalent
Linear Measures	
1 mile = 1760 yards = 5280 feet = 63,360 inches	1.6093 km
1 yard = 3 feet = 36 inches	0.9144 m
1 foot = 12 inches	0.3048 m
1 inch	2.5400 cm
Liquid Measures	
1 gallon (Br.) = 4 quarts = 8 pints = 32 gills = = 160 fluid ounces	4.546 l
1 gallon (Am.) = 4 quarts = 8 pints = 32 gills = = 128 fluid ounces	3.785 l
1 gallon (Br.) = 1.2009 gallon (Am.)	4.546 l
1 pint (Br.) = 4 gills = 20 fluid ounces = = 160 fluid drachms = 9600 minims	0.5683 l
1 pint (Am.) = 4 gills = 16 fluid ounces = = 128 fluid drachms = 7680 minims	0.4732 l
1 fluid ounce (Br.) = 8 fluid drachms = 480 minims	28.41 ml
1 fluid ounce (Am.) = 8 fluid drachms = 480 minims	29.57 ml
1 fluid drachm (Br.) = 60 minims = 3 fluid scruples	3.552 ml
1 fluid drachm (Am.)	3.697 ml
1 fluid scruple (Br.) = 20 minims	1.184 ml
1 minim (Br.)	0.05919 ml
1 minim (Am.)	0.06161 ml
Avoirdupois Weight	
1 Br. pound (lb) = 16 ounces = 256 drachms = = 7000 grains	453.59 g
1 Br. long ton = 2240 pounds	1016.05 kg
1 Br. short ton = 2000 pounds	907.185 kg
1 ounce = 16 drachms = 437.5 grains	28.35 g
1 drachm = 27.34 grains	1.772 g
1 grain	0.0648 g
Units of Energy	
1 Br. foot·pound = 0.1383 kgf·m	1.356 J
1 Br. horsepower·hour (hp·h) = 0.746 kWh = = 274,000 kgf·m = 1.014 hp·h (metric system)	4690 kJ

Table 57 (continued)

Name	Metric equivalent
1 British thermal unit (BTU) = quantity of heat that raises the temperature of 1 Br. pound of water by 1°F	0.252 kcal
Units of Power	
1 Br. foot·pound/second = 0.0018144 hp (metric system)	1.356 W
1 Br. horsepower = 1.014 metric horsepower . .	0.746 kW

Table 58

Simplified Table of Five-Place Logarithms

Every line gives the proportional parts of the *mean* values of the
of their real values). Such a simplification leads to errors in mantissas
and convenient to use as the tables of four-place logarithms.

A. Logarithms

N	0	1	2	3	4	5	6
10	00 000	00 432	00 860	01 284	01 703	02 119	02 531
11	04 139	04 532	04 922	05 308	05 690	06 070	06 646
12	07 918	08 279	08 636	08 991	09 342	09 691	10 037
13	11 394	11 727	12 057	12 385	12 710	13 033	13 354
14	14 613	14 922	15 229	15 534	15 836	16 137	16 435
15	17 609	17 898	18 184	18 469	18 752	19 033	19 312
16	20 412	20 683	20 951	21 219	21 484	21 748	22 011
17	23 045	23 300	23 553	23 805	24 055	24 304	24 551
18	25 527	25 768	26 007	26 245	26 482	26 717	26 951
19	27 875	28 103	28 330	28 556	28 780	29 003	29 226
20	30 103	30 320	30 535	30 750	30 963	31 175	31 387
21	32 222	32 428	32 634	32 838	33 041	33 244	33 445
22	34 242	34 439	34 635	34 830	35 025	35 218	35 411

differences between the numbers which stand on the given line (instead of logarithms, but they are not over 0.00002. This table is as easy

7	8	9	Proportional parts of the *mean* values of differences								
			1	2	3	4	5	6	7	8	9
			42	85	127	170	212	254	297	339	381
02 938	03 342	03 743	40	81	121	162	202	242	283	323	364
			37	77	116	154	193	232	270	309	348
06 819	07 188	07 555	37	74	111	148	185	222	259	296	333
			36	71	106	142	177	213	248	284	319
10 380	10 721	11 059	34	68	102	136	170	204	238	272	307
			33	66	98	131	164	197	229	262	295
13 672	13 988	14 301	32	63	95	126	158	190	221	253	284
			30	61	91	122	152	183	213	244	274
16 732	17 026	17 319	29	59	88	118	147	177	206	236	265
			28	57	85	114	142	171	199	228	256
19 590	19 866	20 140	28	55	83	110	138	165	193	221	248
			27	53	80	107	134	160	187	214	240
22 272	22 531	22 789	26	52	78	104	130	156	182	208	233
			26	50	76	101	126	151	176	201	227
24 797	25 042	25 285	25	49	73	58	122	147	171	196	220
			24	48	71	95	119	143	167	190	214
27 184	27 416	27 646	23	46	69	93	116	139	162	185	208
			23	45	68	90	113	135	158	180	203
29 447	29 667	29 885	22	44	66	88	110	132	154	176	198
31 597	31 806	32 015	21	43	64	85	106	127	148	170	190
33 646	33 846	34 044	20	41	61	81	101	121	141	162	182
35 603	35 793	35 984	20	39	58	77	97	116	135	154	174

Logarithms

N	0	1	2	3	4	5	6
23	36 173	36 361	36 549	36 736	36 922	37 107	37 291
24	38 021	38 202	38 382	38 561	38 739	38 917	39 094
25	39 794	39 967	40 140	40 312	40 483	40 654	40 824
26	41 497	41 664	41 830	41 996	42 160	42 325	42 488
27	43 136	43 297	43 457	43 616	43 775	43 933	44 091
28	44 716	44 871	45 025	45 179	45 332	45 484	45 637
29	46 240	46 389	46 538	46 687	46 835	46 982	47 129
30	47 712	47 857	48 001	48 144	48 287	48 430	48 572
31	49 136	49 276	49 415	49 554	49 693	49 831	49 969
32	50 515	50 650	50 786	50 920	51 054	51 188	51 322
33	51 851	51 983	52 114	52 244	52 375	52 504	52 634
34	53 148	53 275	53 403	53 529	53 656	53 782	53 908
35	54 407	54 531	54 654	54 777	54 900	55 023	55 145
36	55 630	55 751	55 871	55 991	56 110	56 229	56 348
37	56 820	56 937	57 054	57 171	57 287	57 403	57 519
38	57 978	58 092	58 206	58 320	58 433	58 546	58 659
39	59 106	59 218	59 329	59 439	59 550	59 660	59 770
40	60 206	60 314	60 423	60 531	60 638	60 746	60 853
41	61 278	61 384	61 490	61 595	61 700	61 805	61 909
42	62 325	62 428	62 531	62 634	62 737	62 839	62 941
43	63 347	63 448	63 548	63 649	63 749	63 849	63 949
44	64 345	64 444	64 542	64 640	64 738	64 836	64 933
45	65 321	65 418	65 514	66 610	65 706	65 801	65 896
46	66 276	66 370	66 464	66 558	66 652	66 745	66 839
47	67 210	67 302	67 394	67 486	67 578	67 669	67 761
48	68 124	68 215	68 305	68 395	68 485	68 574	68 664
49	69 020	69 108	69 197	69 285	69 373	69 461	69 548
50	69 897	69 984	70 070	70 157	70 243	70 329	70 415
51	70 757	70 842	70 927	71 012	71 096	71 181	71 265
52	71 600	71 684	71 767	71 850	71 933	72 016	72 099
53	72 428	72 509	72 591	72 673	72 754	72 835	72 916
54	73 239	73 320	73 400	73 480	73 560	73 640	73 719
55	74 036	74 115	74 194	74 273	74 351	74 429	74 507
56	74 819	74 896	74 974	75 051	75 128	75 205	75 282
57	75 587	75 664	75 740	75 815	75 891	75 967	76 042
58	76 343	76 418	76 492	76 567	76 641	76 716	76 790
59	77 085	77 159	77 232	77 305	77 379	77 452	77 525

Table 58 (continued)

7	8	9	Proportional parts of the *mean* values of differences								
			1	2	3	4	5	6	7	8	9
37 475	37 658	37 840	19	37	56	74	93	111	130	148	167
39 270	39 445	39 620	18	35	53	71	89	106	124	142	159
40 993	41 162	41 330	17	34	51	68	85	102	119	136	153
42 651	42 813	42 975	16	33	49	66	82	98	115	131	148
44 248	44 404	44 560	16	32	47	63	79	95	111	126	142
45 788	45 939	46 090	15	30	46	61	76	91	107	122	137
47 276	47 422	47 567	15	29	44	59	74	88	103	118	132
48 714	48 855	48 996	14	29	43	57	72	86	100	114	129
50 106	50 243	50 379	14	28	41	55	69	83	97	110	124
51 455	51 587	51 720	13	27	40	54	67	80	94	107	121
52 763	52 892	53 020	13	26	39	52	65	78	91	104	117
54 033	54 158	54 283	13	25	38	50	63	76	88	101	113
55 267	55 388	55 509	12	24	37	49	61	73	85	98	110
56 467	56 585	56 703	12	24	36	48	60	71	83	95	104
57 634	57 749	57 864	12	23	35	46	58	70	81	93	104
58 771	58 883	58 995	11	23	34	45	57	68	79	90	102
59 879	59 988	60 097	11	22	33	44	55	66	77	88	99
60 959	61 066	61 172	11	21	32	43	54	64	75	86	97
62 014	62 118	62 221	10	21	31	42	53	63	74	84	95
63 043	63 144	63 246	10	20	31	41	51	61	71	82	92
64 048	64 147	64 246	10	20	30	40	50	60	70	80	90
65 031	65 128	65 225	10	20	29	39	49	59	68	78	88
65 992	66 087	66 181	10	19	29	38	48	57	67	76	86
66 932	67 025	67 117	9	19	28	37	47	56	65	74	84
67 852	67 943	68 034	9	18	27	36	46	55	64	73	82
68 753	68 842	68 931	9	18	27	36	45	53	63	72	81
69 636	69 723	69 810	9	18	26	35	44	53	62	70	79
70 501	70 586	70 672	9	17	26	34	43	52	60	69	77
71 349	71 433	71 517	8	17	25	34	42	50	59	67	76
72 181	72 263	72 346	8	17	25	33	42	50	58	66	75
72 997	73 078	73 159	8	16	24	32	41	49	57	65	73
73 799	73 878	73 957	8	16	24	32	40	48	56	64	72
74 586	74 663	74 741	8	16	23	31	39	47	55	63	70
75 358	75 435	75 511	8	15	23	31	39	46	54	62	69
76 118	76 193	76 268	8	15	23	30	38	45	53	60	68
76 864	76 938	77 012	7	15	22	30	37	44	52	59	67
77 597	77 670	77 743	7	15	22	29	37	44	51	58	66

Logarithms

N	0	1	2	3	4	5	6
60	77 815	77 887	77 960	78 032	78 104	78 176	78 247
61	78 533	78 604	78 675	78 746	78 817	78 888	78 958
62	79 239	79 309	79 379	79 449	79 518	79 588	79 657
63	79 934	80 003	80 072	80 140	80 209	80 277	80 346
64	80 618	80 686	80 754	80 821	80 889	80 956	81 023
65	81 291	81 358	81 425	81 491	81 558	81 624	81 690
66	81 954	82 020	82 086	82 151	82 217	82 282	82 347
67	82 607	82 672	82 737	82 802	82 866	82 930	82 995
68	83 251	83 315	83 378	83 442	83 506	83 569	83 632
69	83 885	83 948	84 011	84 073	84 136	84 198	84 261
70	84 510	84 572	84 634	84 696	84 757	84 819	84 880
71	85 126	85 187	85 248	85 309	85 370	85 431	85 491
72	85 733	85 794	85 854	85 914	85 974	86 034	86 094
73	86 332	86 392	86 451	86 510	86 570	86 629	86 688
74	86 923	86 982	87 040	87 099	87 157	87 216	87 274
75	87 506	87 564	87 622	87 679	87 737	87 795	87 852
76	88 081	88 138	88 195	88 252	88 309	88 366	88 423
77	88 649	88 705	88 762	88 818	88 874	88 930	88 986
78	89 209	89 265	89 321	89 376	89 432	89 487	89 542
79	89 763	89 818	89 873	89 927	89 982	90 037	90 091
80	90 309	90 363	90 417	90 472	90 526	90 580	90 634
81	90 848	90 902	90 956	91 009	91 062	91 116	91 169
82	91 381	91 434	91 487	91 540	91 593	91 645	91 698
83	91 908	91 960	92 012	92 064	92 117	92 169	92 221
84	92 428	92 480	92 531	92 583	92 634	92 686	92 737
85	92 942	92 993	93 044	93 095	93 146	93 197	93 247
86	93 450	93 500	93 551	93 601	93 651	93 702	93 752
87	93 952	94 002	94 052	94 101	94 151	94 201	94 250
88	94 448	94 498	94 547	94 596	94 645	94 694	94 743
89	94 939	94 988	95 036	95 085	95 134	95 182	95 231
90	95 424	95 472	95 521	95 569	95 617	95 665	95 713
91	95 904	95 952	95 999	96 047	96 095	96 142	96 190
92	96 379	96 426	96 473	96 520	96 567	96 614	96 661
93	96 848	96 895	96 942	96 988	97 035	97 081	97 128
94	97 313	97 359	97 405	97 451	97 497	97 543	97 589

Table 58 (*continued*)

7	8	9	Proportional parts of the *mean* valuec of differences								
			1	2	3	4	5	6	7	8	9
78 319	78 390	78 462	7	14	22	29	36	43	50	58	65
79 029	79 099	79 169	7	14	21	28	36	43	50	57	64
79 727	79 796	79 865	7	14	21	28	35	41	48	55	62
80 414	80 482	80 550	7	14	20	27	34	41	48	54	61
81 090	81 158	81 224	7	13	20	27	34	40	47	54	60
81 757	81 823	81 889	7	13	20	26	33	40	46	53	59
82 413	82 478	82 543	7	13	20	26	33	39	46	52	59
83 059	83 123	83 187	6	13	19	26	32	38	45	51	58
83 696	83 759	83 822	6	13	19	25	32	38	44	50	57
84 323	84 386	84 448	6	12	19	25	31	37	43	50	56
84 942	85 003	85 065	6	12	19	25	31	37	43	50	56
85 552	85 612	85 673	6	12	18	24	31	37	43	49	55
86 153	86 213	86 273	6	12	18	24	30	36	42	48	54
86 747	86 806	86 864	6	12	18	24	30	35	41	47	53
87 332	87 390	87 448	6	12	17	23	29	35	41	46	52
87 910	87 967	88 024	6	12	17	23	29	35	41	46	52
88 480	88 536	88 593	6	11	17	23	29	34	40	46	51
89 042	89 098	89 154	6	11	17	22	28	34	39	45	50
89 597	89 653	89 708	6	11	17	22	28	33	39	44	50
90 146	90 200	90 255	6	11	17	22	28	33	39	44	50
90 687	90 741	90 795	5	11	16	22	27	32	38	43	49
91 222	91 275	91 328	5	11	16	21	27	32	37	42	48
91 751	91 803	91 855	5	11	16	21	27	32	37	42	48
92 273	92 324	92 376	5	10	16	21	26	31	36	42	47
92 788	92 840	92 891	5	10	15	20	26	31	36	41	46
93 298	93 349	93 399	5	10	15	20	26	31	36	41	46
93 802	93 852	93 902	5	10	15	20	25	30	35	40	45
94 300	94 349	94 399	5	10	15	20	25	30	35	40	45
94 792	94 841	94 890	5	10	15	20	25	29	34	39	44
95 279	95 328	95 376	5	10	15	19	24	29	34	39	44
95 761	95 809	95 856	5	10	14	19	24	29	34	38	43
96 237	96 284	96 332	5	9	14	19	24	28	33	38	42
96 708	96 755	96 802	5	9	14	19	24	28	33	38	42
97 174	97 220	97 267	5	9	14	18	23	28	32	38	42
97 635	97 681	97 727	5	9	14	18	23	28	32	37	42

Logarithms

N	0	1	2	3	4	5	6
95	97 772	97 818	97 864	97 909	97 955	98 000	98 046
96	98 227	98 272	98 318	98 363	98 408	98 453	98 498
97	98 677	98 722	98 767	98 811	98 856	98 900	98 945
98	99 123	99 167	99 211	99 255	99 300	99 344	99 388
99	99 564	99 607	99 651	99 695	99 739	99 782	99 826

B. Antilogarithms

log	0	1	2	3	4	5	6
.00	10 000	10 023	10 046	10 069	10 093	10 116	10 139
.01	10 233	10 257	10 280	10 304	10 328	10 351	10 375
.02	10 471	10 495	10 520	10 544	10 568	10 593	10 617
.03	10 715	10 740	10 765	10 789	10 814	10 839	10 864
.04	10 965	10 990	11 015	11 041	11 066	11 092	11 117
.05	11 220	11 246	11 272	11 298	11 324	11 350	11 376
.06	11 482	11 508	11 535	11 561	11 588	11 614	11 641
.07	11 749	11 776	11 803	11 830	11 858	11 885	11 912
.08	12 023	12 050	12 078	12 106	12 134	12 162	12 190
.09	12 303	12 331	12 359	12 388	12 417	12 445	12 474
.10	12 589	12 618	12 647	12 677	12 706	12 735	12 764
.11	12 882	12 912	12 942	12 972	13 002	13 032	13 062
.12	13 183	13 213	13 243	13 274	13 305	13 335	13 366
.13	13 490	13 521	13 552	13 583	13 614	13 646	13 677
.14	13 804	13 836	13 868	13 900	13 932	13 964	13 996
.15	14 125	14 158	14 191	14 223	14 256	14 289	14 322
.16	14 454	14 488	14 521	14 555	14 588	14 622	14 655
.17	14 791	14 825	14 859	14 894	14 928	14 962	14 997
.18	15 136	15 171	15 205	15 241	15 276	15 311	15 346
.19	15 488	15 524	15 560	15 596	15 631	15 668	15 704
.20	15 849	15 885	15 922	15 959	15 996	16 032	16 069
.21	16 218	16 255	16 293	16 331	16 368	16 406	16 444
.22	16 596	16 634	16 672	16 711	16 749	16 788	16 827
.23	16 982	17 022	17 061	17 100	17 140	17 179	17 219
.24	17 378	17 418	17 458	17 498	17 539	17 579	17 620

Table 58 (continued)

7	8	9	Proportional parts of the *mean* values of differences								
			1	2	3	4	5	6	7	8	9
98 091	98 137	98 182	5	9	14	18	23	27	32	36	41
98 543	98 588	98 632	5	9	14	18	23	27	32	36	41
98 989	99 034	99 078	4	9	13	18	22	27	31	36	40
99 432	99 476	99 520	4	9	13	18	22	26	31	35	40
99 870	99 913	99 957	4	9	13	17	22	26	31	35	39

7	8	9	Proportional parts of the *mean* values of differences								
			1	2	3	4	5	6	7	8	9
10 162	10 186	10 209	2	5	7	9	12	14	16	19	21
10 399	10 423	10 447	2	5	7	10	12	14	17	19	21
10 641	10 666	10 691	2	5	7	10	12	15	17	20	22
10 889	10 914	10 940	3	5	8	10	13	15	18	20	23
11 143	11 169	11 194	3	5	8	10	13	15	18	20	23
11 402	11 429	11 455	3	5	8	11	13	16	18	21	24
11 668	11 695	11 722	3	5	8	11	13	16	19	21	24
11 940	11 967	11 995	3	5	8	11	14	16	19	22	25
12 218	12 246	12 274	3	6	8	11	14	17	20	22	25
12 503	12 531	12 560	3	6	9	11	14	17	20	23	26
12 794	12 823	12 853	3	6	9	12	15	18	21	24	26
13 092	13 122	13 152	3	6	9	12	15	18	21	24	27
13 397	13 428	13 459	3	6	9	12	15	18	21	25	28
13 709	13 740	13 772	3	6	9	13	16	19	22	25	28
14 028	14 060	14 093	3	6	10	13	16	19	22	26	29
14 355	14 388	14 421	3	7	10	13	16	20	23	26	30
14 689	14 723	14 757	3	7	10	13	17	20	24	27	30
15 031	15 066	15 101	3	7	10	14	17	21	24	28	31
15 382	15 417	15 453	4	7	11	14	18	21	25	28	32
15 740	15 776	15 812	4	7	11	14	18	22	25	29	32
16 106	16 144	16 181	4	7	11	15	18	22	26	30	33
16 482	16 520	16 558	4	8	11	15	19	23	26	30	34
16 866	16 904	16 943	4	8	12	15	19	23	27	31	35
17 258	17 298	17 338	4	8	12	16	20	24	28	32	36
17 660	17 701	17 742	4	8	12	16	20	24	28	32	36

Antilogarithms

log	0	1	2	3	4	5	6
.25	17 783	17 824	17 865	17 906	17 947	17 989	18 030
.26	18 197	18 239	18 281	18 323	18 365	18 408	18 450
.27	18 621	18 664	18 707	18 750	18 793	18 836	18 880
.28	19 055	19 099	19 143	19 187	19 231	19 275	19 320
.29	19 498	19 543	19 588	19 634	19 679	19 724	19 770
.30	19 953	19 999	20 045	20 091	20 137	20 184	20 230
.31	20 417	20 464	20 512	20 559	20 606	20 654	20 701
.32	20 893	20 941	20 989	21 038	21 086	21 135	21 184
.33	21 380	21 429	21 478	21 528	21 577	21 627	21 677
.34	21 878	21 928	21 979	22 029	22 080	22 131	22 182
.35	22 387	22 439	22 491	22 542	22 594	22 646	22 699
.36	22 909	22 961	23 014	23 067	23 121	23 174	23 227
.37	23 442	23 496	23 550	23 605	23 659	23 714	23 768
.38	23 988	24 044	24 099	24 155	24 210	24 266	24 322
.39	24 547	24 604	24 660	24 717	24 774	24 831	24 889
.40	25 119	25 177	25 236	25 293	25 351	25 410	25 468
.41	25 704	25 763	25 823	25 882	25 942	26 002	26 062
.42	26 303	26 363	26 424	26 485	26 546	26 607	26 669
.43	26 915	26 977	27 040	27 102	27 164	27 227	27 290
.44	27 542	27 606	27 669	27 733	27 797	27 861	27 925
.45	28 184	28 249	28 314	28 379	28 445	28 510	28 576
.46	28 840	28 907	28 973	29 040	29 107	29 174	29 242
.47	29 512	29 580	29 648	29 717	29 785	29 854	29 923
.48	30 200	30 269	30 339	30 409	30 479	30 549	30 620
.49	30 903	30 974	31 046	31 117	31 189	31 261	31 333
.50	31 623	31 696	31 769	31 842	31 916	31 989	32 063
.51	32 359	32 434	32 509	32 584	32 659	32 735	32 809
.52	33 113	33 189	33 266	33 343	33 420	33 497	33 574
.53	33 884	33 963	34 041	34 119	34 198	34 277	34 356
.54	34 674	34 754	34 834	34 914	34 995	35 075	35 156
.55	35 481	35 563	35 645	35 727	35 810	35 892	35 975
.56	36 308	36 392	36 475	36 559	36 644	36 728	36 813
.57	37 154	37 239	37 325	37 411	37 497	37 584	37 670
.58	38 019	38 107	38 194	38 282	38 371	38 459	38 548
.59	38 905	38 994	39 084	39 174	39 264	39 355	39 446

Table 58 (continued)

7	8	9	Proportional parts of the *mean* values of differences								
			1	2	3	4	5	6	7	8	9
18 072	18 113	18 155	4	8	12	17	21	25	29	33	37
18 493	18 535	18 578	4	8	13	17	21	25	30	34	38
18 923	18 967	19 011	4	9	13	17	22	26	30	35	39
19 364	19 409	19 454	4	9	13	18	22	26	31	35	40
19 815	19 861	19 907	5	9	14	18	23	27	32	36	41
20 277	20 324	20 370	5	9	14	19	23	28	32	37	42
20 749	20 797	20 845	5	10	14	19	24	29	33	38	43
21 232	21 281	21 330	5	10	15	19	24	29	34	39	44
21 727	21 777	21 826	5	10	15	20	25	30	35	40	45
22 233	22 284	22 336	5	10	15	20	25	31	36	41	46
22 751	22 803	22 856	5	10	16	21	26	31	37	42	47
23 281	23 336	23 388	5	11	16	21	27	32	37	43	48
23 823	23 878	23 933	5	11	16	22	27	33	38	44	49
24 378	24 434	24 491	6	11	17	22	28	34	39	45	50
24 946	25 003	25 061	6	11	17	23	29	34	40	46	51
25 527	25 586	25 645	6	12	18	23	29	35	41	47	53
26 122	26 182	26 242	6	12	18	24	30	36	42	48	54
26 730	26 792	26 853	6	12	18	24	31	37	43	49	55
27 353	27 416	27 479	6	13	19	25	31	38	44	50	56
27 990	28 054	28 119	6	13	19	26	32	39	45	51	58
28 642	28 708	28 774	7	13	20	26	33	39	46	52	59
29 309	29 376	29 444	7	13	20	27	34	40	47	54	60
29 992	30 061	30 130	7	14	21	28	34	41	48	55	62
30 690	30 761	30 832	7	14	21	28	35	42	49	56	63
31 405	31 477	31 550	7	14	22	29	36	43	50	58	65
32 137	32 211	32 285	7	15	22	29	37	44	52	59	66
32 885	32 961	33 037	8	15	23	30	38	45	53	60	68
33 651	33 729	33 806	8	15	23	31	39	46	54	62	69
34 435	34 514	34 594	8	16	24	32	40	47	55	63	71
35 237	35 318	35 400	8	16	24	32	40	48	56	65	73
36 058	36 141	36 224	8	16	25	33	41	50	58	66	74
36 898	36 983	37 068	8	17	25	34	42	51	59	68	76
37 757	37 844	37 931	9	17	26	35	43	52	61	69	78
38 637	38 726	38 815	9	18	27	35	44	53	62	71	80
39 537	39 628	39 719	9	18	27	36	45	54	63	72	82

Antilogarithms

log	0	1	2	3	4	5	6
.60	39 811	39 902	39 994	40 087	40 179	40 272	40 365
.61	40 738	40 832	40 926	41 020	41 115	41 210	41 305
.62	41 687	41 783	41 879	41 976	42 073	42 170	42 267
.63	42 658	42 756	42 855	42 954	43 053	43 152	43 251
.64	43 652	43 752	43 853	43 954	44 055	44 157	44 259
.65	44 668	44 771	44 875	44 978	45 082	45 186	45 290
.66	45 709	45 814	45 920	46 026	46 132	46 238	46 345
.67	46 774	46 881	46 989	47 098	47 206	47 315	47 424
.68	47 863	47 973	48 084	48 195	48 306	48 417	48 529
.69	48 978	49 091	49 204	49 317	49 431	49 545	49 659
.70	50 119	50 234	50 350	50 466	50 582	50 699	50 816
.71	51 286	51 404	51 523	51 642	51 761	51 880	52 000
.72	52 481	52 602	52 723	52 845	52 966	53 088	53 211
.73	53 703	53 827	53 951	54 075	54 200	54 325	54 450
.74	54 954	55 081	55 208	55 336	55 463	55 590	55 719
.75	56 234	56 364	56 494	56 624	56 754	56 855	57 016
.76	57 544	57 677	57 810	57 943	58 076	58 210	58 345
.77	58 884	59 020	59 156	59 293	59 429	59 566	59 704
.78	60 256	60 395	60 534	60 674	60 814	60 954	61 094
.79	61 659	61 802	61 944	62 087	62 230	62 373	62 517
.80	63 096	63 241	63 387	63 533	63 680	63 826	63 973
.81	64 565	64 714	64 863	65 013	65 163	65 313	65 464
.82	66 069	66 222	66 374	66 527	66 681	66 834	66 988
.83	67 608	67 764	67 920	68 077	68 234	68 391	68 549
.84	69 183	69 343	69 503	69 663	69 823	69 984	70 146
.85	70 795	70 958	71 121	71 285	71 450	71 614	71 779
.86	72 444	72 611	72 778	72 946	73 114	73 282	73 451
.87	74 131	74 302	74 473	74 645	74 817	74 989	75 162
.88	75 858	76 033	76 208	76 384	76 560	76 736	76 913
.89	77 625	77 804	77 983	78 163	78 343	78 524	78 705
.90	79 433	79 616	79 799	79 983	80 168	80 353	80 538
.91	81 283	81 470	81 658	81 846	82 035	82 224	82 414
.92	83 176	83 368	83 560	83 753	83 946	84 140	84 333
.93	85 114	85 310	85 507	85 704	85 901	86 099	86 298
.94	87 096	87 297	87 498	87 700	87 902	88 105	88 308
.95	89 125	89 331	89 536	89 743	89 950	90 157	90 365
.96	91 201	91 411	91 622	91 833	92 045	92 257	92 470
.97	93 325	93 541	93 756	93 972	94 189	94 406	94 624
.98	95 499	95 719	95 940	96 161	96 383	96 605	96 828
.99	97 724	97 949	98 175	98 401	98 628	98 855	96 083

Table 58 (*continued*)

7	8	9	Proportional parts of the *mean* values of differences								
			1	2	3	4	5	6	7	8	9
40 458	40 551	40 644	9	19	28	37	46	55	65	74	83
41 400	41 495	41 591	9	19	28	38	47	57	66	76	85
42 364	42 462	42 560	10	19	29	39	49	58	68	78	87
43 351	43 451	43 551	10	20	30	40	50	60	70	80	89
44 361	44 463	44 566	10	20	30	41	51	61	71	81	91
45 394	45 499	45 604	10	21	31	42	52	62	73	83	94
46 452	46 559	46 666	11	21	32	43	53	64	75	85	96
47 534	47 643	47 753	11	22	33	44	54	65	76	87	98
48 641	48 753	48 865	11	22	33	45	56	67	78	89	100
49 774	49 888	50 003	11	23	34	46	57	68	80	91	103
50 933	51 050	51 168	12	23	35	47	58	70	82	93	105
52 119	52 240	52 360	12	24	36	48	60	72	84	96	108
53 333	53 456	53 580	12	24	37	49	61	73	85	98	110
54 576	54 702	54 828	13	25	38	50	63	75	88	100	113
55 847	55 976	56 105	13	26	38	51	64	77	90	102	115
57 148	57 280	57 412	13	26	39	52	66	79	92	105	118
58 479	58 614	58 749	13	27	40	54	67	80	94	107	121
59 841	59 979	60 117	14	27	41	55	69	82	96	110	123
61 235	61 376	61 518	14	28	42	56	70	84	98	112	126
62 661	62 806	62 951	14	29	43	58	72	86	101	115	130
64 121	64 269	64 417	15	29	44	59	74	88	103	118	132
65 615	65 766	65 917	15	30	45	60	75	90	105	120	135
67 143	67 298	67 453	15	31	46	62	77	92	108	123	139
68 707	68 865	69 024	16	32	47	63	79	95	110	126	142
70 307	70 469	70 632	16	32	48	64	81	97	113	129	145
71 945	72 111	72 277	17	33	50	66	83	99	116	132	149
73 621	73 790	73 961	17	34	51	68	85	101	118	135	152
75 336	75 509	75 683	17	35	52	69	87	104	121	138	156
77 090	77 268	77 446	18	35	53	71	89	107	125	142	159
78 886	79 068	79 250	18	36	54	72	91	109	127	145	163
80 724	80 910	81 096	19	37	56	74	93	111	130	148	167
82 604	82 794	82 985	19	38	57	76	95	113	132	151	170
84 528	84 723	84 918	19	39	58	78	97	116	136	155	175
86 497	86 696	86 896	20	40	60	79	99	119	139	158	178
88 512	88 716	88 920	20	41	61	81	102	122	142	162	183
90 573	90 782	90 991	21	42	62	83	104	125	146	166	187
92 683	92 897	93 111	21	42	64	85	106	127	149	170	191
94 842	95 060	95 280	22	43	65	87	109	130	152	174	195
97 051	97 275	97 499	22	44	67	89	111	133	155	178	200
99 312	99 541	99 770	23	46	68	91	114	137	160	182	205

Appendices

Examples of Using Some Tables

Table 7

Analytical and Stoichiometric Multipliers (Factors)

The table is intended above all for calculations connected with analytical determinations by gravimetric methods.

When the content of a component is being determined in some material, two cases are possible.

1. *The unknown component is weighed in the form in which it is desirable to express its content in the substance being analysed*; for example, in determining the Cu content in bronze, copper is separated by electrolysis and weighed as such, and in another case, SiO_2 from the mineral is weighed in the form of SiO_2, whose form usually expresses the Si content of minerals in rocks. In these cases, the percentage of the unknown component is calculated by the simple formula

$$x = \frac{a \times 100}{g}\ \%$$

where a = mass of the separated component;

g = weighed portion of a substance taken for analysis (a and g are expressed in the same mass units).

For calculation, two logarithms must be found without using Table 7.

2. *The unknown component is weighed in a form that is different from the one in which it is desirable to express the result of the analysis*; for example, the determination of P is completed by weighing a calcined precipitate of $Mg_2P_2O_7$ or, in determining Si in steel, the analysis is completed likewise by weighing SiO_2, as in the case of analysing the mineral, but the result must be expressed in the percentage of the element (Si). Sometimes, the weighed substance does not contain the element being determined. Thus, in determining N in ammonium salt, ammonium is occasionally precipitated in the form of $(NH_4)_2PtCl_6$ which is then calcined; Pt obtained is weighed. The content of Pt is used to calculate the percentage of N in the salt being analysed.

In all these cases it is obviously necessary to calculate the amount of the unknown component to which the found mass of the weighed substance (a) corresponds. Therefore, in determining Si, mass a must be divided by the molecular weight of SiO_2 and multiplied by the atomic weight of Si, i.e., $\frac{a\,Si}{SiO_2}$; in determining P, the found mass a must be divided by the molecular weight of $Mg_2P_2O_7$ and multiplied by the double atomic weight of P (since the $Mg_2P_2O_7$ molecule contains 2P), i.e., $\frac{a\,2\mathrm{P}}{\mathrm{Mg_2P_2O_7}}$; *in determining N, the found mass a must* be divided by the atomic weight of Pt and multiplied by the double atomic weight of N, i.e., $\frac{a\,2\mathrm{N}}{\mathrm{Pt}}$, since in the $\mathrm{(NH_4)_2PtCl_6}$ compound, two atoms of N combine with one atom of Pt. All the values of these fractions, i.e., $\frac{\mathrm{Si}}{\mathrm{SiO_2}}$, $\frac{2\mathrm{P}}{\mathrm{Mg_2P_2O_7}}$, $\frac{2\mathrm{N}}{\mathrm{Pt}}$, etc., and their logarithms, are given in Table 7, where they are called multipliers and designated by the letter f (they are also called *factors, conversion factors, chemical multipliers*). Thus, the content of the component being determined in the weighed substance will be af, and its percentage in the material being analysed will be:

$$x = \frac{af \times 100}{g}\ \%$$

Thus, the calculation is performed by finding three logarithms (one from Table 7, and two from the common logarithm table), adding two of them and subtracting the third one.

Since the operation of addition and subtraction cannot be performed in one column, it is necessary to learn how to quickly find its complement to unity by logarithm. Then, the entire operation consists in adding three mantissas: $\log x = \log a + \log f + (1 - \log g)$. The characteristics and the whole number 2 ($\log 100 = 2$) are not taken into account. When the operation is completed and the number x is found by its logarithm, it is easy to find the proper place of the decimal point in it, since it is always known whether the material being analysed contains, say, 8.3 or 83 or 0.83 per cent of the component being determined.

To find the complement of $\log g$ to unity, the last figure of the mantissa is subtracted from 10, and the remaining figures are subtracted from 9; for example, if the mantissa of $\log g$ is 34 906, its complement to unity is 65 094.

Examples of Calculating the Results of Gravimetric, Analytical Determinations

Example 1. To determine Cu in brass, a portion of a shaving g weighing 1.1238 g is taken. The mass of a pure platinum electrode is 12.4826 g; the mass of the same electrode coated with deposited Cu is 13.2965 g after drying. Find the percentage of Cu in the alloy.

The mass of deposited Cu a = 13.2965 g − 12.4826 g = 0.8139 g. The unknown percentage of Cu is $x = \frac{0.8139 \times 100}{1.1238}\ \%$. We find the logarithms in Table 58 (p. 448) and write down the mantissas without the characteristics:

$$\begin{array}{r} 91\,057 \\ -05\,069 \\ \hline \log x = 85\,988;\ x = 72.42\% \end{array}$$

It is easy to see from the calculating formula that the final result will have two digits before the decimal point. In working out this example, we did not have to use the multipliers of Table 7, since the component of brass (Cu) being determined was weighed in the form of metal.

Example 2. To determine Mg in limestone, a portion weighing 1.2456 g is taken. After SiO_2, Fe, Al and Ca are separated, Mg is precipitated in the form of $MgNH_4PO_4$ which by calcination is converted to $Mg_2P_2O_7$; the mass of the calcined precipitate $a = 0.0551$ g. Find the percentage of magnesium in the limestone.

We find in the common logarithm table: $\log g = \log 1.2456 =$ $= 09\ 540$; $\log a = \log 0.0551 = 74\ 115$. As in the preceding example, we find only the mantissas.

In Table 7 we find Mg in the first column, $Mg_2P_2O_7$ in the next column, and then on the same line the value of multiplier f equal to 0.2184, and $\log f$ equal to 33 930. Now we add:

$$\begin{aligned} \log a &= 74\ 115 \\ \log f &= 33\ 930 \\ 1 - \log g &= 90\ 460 \\ \hline \log x &= 98\ 505 \end{aligned}$$

The Mg content is 0.966 or 0.97%.

Since in the mass of the calcined precipitate weighing 0.0551 g, the maximum absolute error is ±0.0002 g (an inaccuracy of ordinary weighings on an analytical balance), which is 0.4% of the relative error, the same maximum relative error will be also in the final result (rule 4, p. 11), i.e., the answer will be 0.966 ± 0.004%. We see that the answer must not have more than three figures after the decimal point, since the third figure is already dubious. However, considering that during the analysis there may be other sources of errors besides the inaccuracy in weighing, it is expedient to round the result obtained to 0.97%.

Table 14

Calculation of the Results of Volumetric-Analytical Determinations

In finding the results of volumetric-analytical determinations, unnecessary and intricate calculations are often performed. For example, in calculating the amount of Fe titrated with the $KMnO_4$ solution, the amount of $KMnO_4$ that has reacted is calculated at first, and then the stoichiometric ratio (1 mole of $KMnO_4$: 5 moles of Fe^{2+}) is used to determine the Fe content. This is an intricate way of calculation, and therefore it is unacceptable. To simplify similar calculations the concentrations of solutions are expressed in normalities.

The *normality* or the normal concentration of a solution is the number of gram-equivalents of a solute in one litre of the solution or the number of milligram equivalents in one millilitre of the solution.

Chemical equivalent is a term applied to the active part of an atom or a molecule which:

(a) *in neutralization reactions* corresponds to one hydrogen ion H^+ or one hydroxyl ion OH^- that forms water.

For example, in the reaction $H_3PO_4 + 2NaOH = Na_2HPO_4 + 2H_2O$, two ions of H^+ and two ions of OH^- form two molecules of H_2O. It follows that there are 1/2 molecule of H_3PO_4 and one molecule $\left(\frac{2NaOH}{2}\right)$ of caustic soda per one ion of H^+ or OH^-. These values are their equivalents;

(b) *in oxidation-reduction reactions* corresponds to one electron that a molecule or an ion of a substance accepts or gives off in a given reaction.

For example, $KMnO_4$ reacts as an oxidizing agent in an acid medium according to the equation:

$$MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$$

It follows that there is $1/5MnO_4^-$ or $1/5KMnO_4$ per electron, which are equivalents. Oxalic acid $H_2C_2O_4$ reacts as a reducing agent according to the equation

$$C_2O_4^{2-} - 2e \rightarrow 2CO_2$$

it follows that there is $1/2C_2O_4^{2-}$, or $1/2H_2C_2O_4$, or $1/2H_2C_2O_4 \cdot 2H_2O$ per one electron; these values are the equivalents;

(c) *in precipitation and complexing reactions* corresponds to one ion of a univalent metal, 1/2 ion of a bivalent metal, and so forth, that form a precipitate or a complex compound. Thus, in titrating cyanide with silver salt according to Mohr:

$$Ag^+ + CN^- = AgCN \quad \text{or} \quad AgNO_3 + KCN = AgCN + KNO_3$$

the equivalent of KCN is equal to one molecule, and in titrating the same cyanide according to Denigès:

$$Ag^+ + 2CN^- = Ag(CN)_2^- \quad \text{or} \quad AgNO_3 + 2KCN = KAg(CN)_2 + KNO_3$$

the equivalent of KCN is equal to two molecules.

From the above examples, we see that the *chemical equivalent of a substance is not a constant number*, but depends on the reaction in which the substance participates.

Gram-equivalent (*or milligram-equivalent*) weight of an element or compound is its equivalent weight expressed in grams (or milligrams).

If the concentration (titre) of a titrating solution (sometimes called a standard solution) is expressed by its normality N_s, and E_s is its equivalent weight, every millilitre of the solution will contain N_sE_s mg of the titrating substance. Having used V ml of the solution in the titration, we introduced VN_sE_s mg of the titrating substance into the reaction. Since a reaction occurs always between the quantities of the substances proportional to their equivalents, the quantity of the titrated substance (being determined) will be VN_sE_x mg, where E_x is the equivalent weight of the substance being determined. It follows that for calculations, it is necessary to know only the normality of the titrating solution N_s and the equivalent weight E_x of the substance being determined. The latter can be found in Table 14.

The percentage (x) of the substance being determined in the weighed portion (g) is calculated by the formula:

$$x=\frac{VN_sE_x\times 100}{g}\%\quad\text{or}\quad\frac{VN_sE_x}{g'\cdot 10}\%$$

where g is expressed in mg, and g' in grams.

A. Determination of the Normality of a Titrant (Finding of the Titre)

In establishing the normality of a solution, a certain amount of a starting substance g_s is weighed. The weighed portion is dissolved and the solution obtained is titrated with the solution whose normality (N_x) is to be determined. Suppose V ml is used in titration. Then $VN_xE_s = g_s$ and

$$N_x=\frac{g_s}{VE_s}$$

where E_s is the equivalent weight of the starting substance which can be found in Table 14; the value of g_s is expressed in mg.

The weighed portion of the substance is dissolved in a suitable solvent (usually water) in a volumetric flask, diluted with it to volume (V_1 ml), and a certain volume (V_2 ml) is taken for the titration with a pipette. In this case

$$N_x=\frac{g_sV_2}{V_1VE_s}$$

Example 1. A portion of pure sodium oxalate $Na_2C_2O_4$ dried at 105-110 °C weighing 0.2712 g is dissolved in water. On adding H_2SO_4, the solution is titrated with 39.88 ml of the $KMnO_4$ solution. Calculate the normality of the latter.

In Table 14, we find:

$$\begin{aligned}E_{Na_2C_2O_4} &= 67\ 000;\ \log E_s = 82\ 607\\ \log g_s &= \log 271.2 = 43\ 329\\ \bar{1} - \log V &= \bar{1} - \log 39.88 = 39\ 924\\ \bar{1} - \log E_s &= \bar{1} - \log 67\ 000 = 17\ 393\\ \hline \log N_x &= \bar{1}00\ 646;\ N_x = 0.1015\end{aligned}$$

If the normality of a solution (N_1) is determined according to another solution of known normality (N_2), then V_1 ml of the former is titrated with the latter. Suppose V_2 ml of the latter solution is used in the titration. Then

$$V_1N_1 = V_2N_2$$

$$N_1=N_2\frac{V_2}{V_1}$$

Example 2. The normality of the NaOH solution (N_1) is established according to $0.09854N$ HCl solution. For the titration of 20.00 ml of the former, 21.12 ml of the latter are used. Calculate the normality of the NaOH solution

$$N_1 = \frac{0.09854 \times 21.12}{20.00}$$

$$\begin{array}{r}
\log 0.09854 = 99\ 362 \\
\log 21.12 = 32\ 469 \\
1 - \log 20.00 = 69\ 897 \\
\hline
\log N_1 = 01\ 728;\ N_1 = 0.1041
\end{array}$$

In practice, the concentration of the titrant ($T_{s/x}$, titre of the solution according to the substance being determined) is very often expressed in the amount (in mg or g) of the substance being determined that titrates 1 ml of the T_x solution. Knowing the normality of the solution, it is easy to find its titre by the following formula relative to any substance being determined: $T_{s/x} = N_s E_x$ (E_x can be found in Table 14). For example, the titre of 0.1023N $KMnO_4$ solution relative to iron is $T_{MnO_4^-/Fe} = N_s E_{Fe} = 0.1023 \times 55.847$ mg/ml; its titre relative to iron oxide is $T_{MnO_4^-/Fe_2O_3} = N_s E_{Fe_2O_3} = 0.1023 \times 79.846$, etc. The percentage of the substance being determined is

$$x = \frac{VN_sE_x \times 100}{g} = \frac{VT_{s/x} \times 100}{g}\ \%$$

where g and $T_{s/x}$ are expressed in the same units.

If a titre of a solution relative to a substance is known and if it is necessary to find its normality or titre relative to another substance, the following formulas can be used:

$$N = \frac{T_a}{E_a} = \frac{T_b}{E_b} = \ldots = \frac{T_n}{E_n}$$

hence

$$T_b = T\frac{T_a}{E_a}E_b = NE_b = \ldots;\ T_n = \frac{T_a}{E_a}E_n = NE_n$$

Example 3. The titre of the $KMnO_4$ solution relative to Fe is 0.005483 g/ml. Find the normality of this solution and its titre relative to Cr.

$$N = \frac{T_{MnO_4^-/Fe}}{E_{Fe}};\quad \begin{array}{r}
\log T_{MnO_4^-/Fe} = \log 0.005483 = 73\ 902 \\
1 - \log E_{Fe} = 1 - \log 55.847 = 25\ 300 \\
\hline
\log N = 99\ 202 \\
N = 0.09818
\end{array}$$

$$T_{MnO_4^-/Cr} = \frac{T_{MnO_4^-/Fe}E_{Cr}}{E_{Fe}};$$

$$\begin{aligned} \log T_{\mathrm{MnO_4^-/Fe}} &= 1 - \log 55.847 = 73\,902 \\ 1 - \log E_{\mathrm{Fe}} &= 1 - \log 55.85 = 25\,300 \\ \log E_{\mathrm{Cr}} &= \log 17.332 = 23\,885 \end{aligned}$$

$$\begin{aligned} \log T_{\mathrm{MnO_4^-/Cr}} &= 23\,087 \\ T_{\mathrm{MnO_4^-/Cr}} &= 0.001702 \text{ g} \end{aligned}$$

B. Determination of the Percentage of the Unknown Component in a Test

Example 1. To determine the Na_2CO_3 content in a soda melt, a portion of it weighing 1.100 g is dissolved in water and the solution obtained is titrated with 0.5012*N* H_2SO_4 solution in the presence of a bromophenol blue indicator. What is the percentage of Na_2CO_3 if 35.00 ml of the acid are used in the titration?

Using Table 14 (see A, *Acid-Base Titration*), we find that $E_{Na_2CO_3}$, with a bromophenol blue indicator, is 52.995, $\log E = 72\,423$.

$$\begin{aligned} \log V &= \log 35.00 = 54\,407 \\ \log N_s &= \log 0.5012 = 70\,001 \\ \log E_x &= \log 52.995 = 72\,423 \\ 1 - \log g &= 1 - \log 1.100 = 95\,861 \end{aligned}$$

$$\log x = 92\,692; \quad x = 84.51\%$$

Example 2. Using the same data as in Example 1, find the percentage of CO_2 in the soda melt.

The solution remains the same, but instead of $E_{Na_2CO_3}$, we find $E_{CO_2} = 22.005$; $\log E = 34\,252$ in Table 14.

Summing up:

$$\begin{aligned} \log V &= 54\,407 \\ \log N_s &= 69\,897 \\ \log E_x &= 34\,252 \\ 1 - \log g &= 95\,861 \end{aligned}$$

$$\log x = 54\,417; \quad x = 35.01\%$$

Example 3. Calculate the percentage of Fe in a sample of iron ore if on dissolving a portion of the ore weighing 0.7872 g and reducing Fe by metallic Zn, 47.24 ml of 0.1105*N* $KMnO_4$ solution were used in titration.

From Table 14 (see B, *Oxidation-Reduction Methods*) we have: $E_{Fe} = 55.85$; $\log E = 74\,702$. Addition gives

$$\begin{aligned} \log V &= \log 47.24 = 67\,431 \\ \log N_s &= \log 0.1105 = 04\,336 \\ \log E_x &= \log 55.847 = 74\,700 \\ 1 - \log g &= 1 - \log 0.7872 = 10\,391 \end{aligned}$$

$$\log x = 56\,858; \quad x = 37.03\%$$

Example 4. To determine Mn in steel by the bismuthate method, a portion weighing 1.1452 g is dissolved in HNO_3. In the solution obtained, Mn is oxidized with sodium bismuthate $NaBiO_3$ to $HMnO_4$. The latter is determined by the addition of 40.00 ml of $0.02842N$ solution of Mohr's salt and a back titration with 13.50 ml of $0.03012N$ $KMnO_4$ solution. Find the percentage of Mn in the solution.

Since the product VN gives the number of mg-equiv of *any* substance, it is expedient to perform the calculation by the following formula:

$$x = \frac{(V_aN_a - V_bN_b)\,E_x \cdot 100}{g}\ \%$$

where V_a and N_a = volume and normality of the solution of Mohr's salt, respectively

and V_b and N_b = volume and normality of the $KMnO_4$ solution.

In Table 14 we find that in determining manganese by the bismuthate method, $E_x = E_{\text{Mn}} = 10.9876$; $\log E_x = 04090$.

We have:

$$\begin{array}{rl}
V_aN_a &= 40.00 \times 0.02842 = 1.1368 \text{ mg-equiv}\\
V_bN_b &= 13.50 \times 0.03012 = 0.4066 \text{ mg-equiv}\\
V_aN_a - V_bN_b &= 1.1368 - 0.4066 = 0.7302 \text{ mg-equiv}\\
\log 0.7302 &= 86\ 344\\
\log E_{\text{Mn}} &= 04\ 090\\
1 - \log 1.1452 &= 94\ 110\\
\hline
\log x &= 84\ 544;\ x = 0.70\%
\end{array}$$

Example 5. How much of the $KMnO_4$ solution of the same concentration would be used in the titration of a portion weighing 1.1452 g of the same steel (see Example 4) if Mn was determined not by the bismuthate method, but by Volhard's method?

$$x = \frac{VN_8E_x \cdot 100}{g}\ \%$$

Here g is the weighed portion expressed in milligrams.

In Table 14, we find that, when Mn is determined by Volhard's method, E_{Mn} is 16.4814, $\log E = 21\ 699$.

$$0.70 = \frac{V \times 0.03012 \times 16.4814 \times 100}{1145.2};\quad V = \frac{0.70 \times 1145.2}{0.03012 \times 16.4814 \times 100}$$

$$\begin{array}{rl}
\log 0.70 &= 84\ 510\\
\log 1145.2 &= 05\ 889\\
1 - \log 0.03012 &= 52\ 115\\
1 - \log 16.4814 &= 78\ 301\\
\hline
\log V &= 20\ 815;\ V = 16.15 \text{ ml}
\end{array}$$

Table 16

Calculation of the Results of Gas and Gasometric Analyses

Here are examples of calculations made according to the formulas given on p. 136.

Example 1. The volume of gas (V), measured over water, is 25.6 ml. The temperature of gas $t = 22.8$ °C. Barometer reading $P_t = 720.4$ mm Hg. The temperature of air, measured near the barometer, $t' = 22.4$ °C. Bring the volume of gas to standard conditions.

First of all, the barometer reading is corrected.

To bring it to 0 °C, we should subtract $t'/8$ mm from it. Then, since the gas is collected over water, its pressure in the vessel is less than the pressure of the surrounding air by the value of P_B which is the water vapour pressure at $t = 22.8$ °C. This value must also be subtracted from the barometer reading.

In Table 16, in the "Water" column with $t = 22$ °C we have $P_B = 19.8$ mm Hg, and with $t = 23$ °C, $P_B = 21.1$ mm Hg. The difference between them is 1.3 mm Hg. We find 0.8 of this difference: $0.8 \times 1.3 = 1.0$ mm and add it to 19.8 mm Hg. It follows that P_B at 22.8 °C is $19.8 + 1.0 = 20.8$ mm Hg.

Hence,

$$P_0 = 720.4 - \frac{22.4}{8} - 20.8 = 696.8 \text{ mm Hg}$$

The unknown volume of gas $V_0 = VF$. To find $\log F$, we use section A.

We have:

t, °C	$P_0 = 696$ mm Hg	$P_0 = 696.8$ mm Hg	$P_0 = 697$ mm Hg
22	92 807	92 857	92 870
22.8	—	92 739	—
23	92 660		

The difference between 92 807 and 92 870 is 63. In the table of differences, we find 0.8 of this number and add it to 92 807, we obtain 92 857. The difference between 92 807 and 92 660 is 147. In the table of differences, we find 148, which is the nearest number to it and of which 0.8 is 118.5, subtracting this number from 92 857 we get approximately 92 739.

$$\begin{array}{l} \log V = 40\,824 \\ \log F = 92\,739 \\ \hline \log V_0 = 33\,563; \quad V_0 = 21.66 \approx 21.7 \text{ ml} \end{array}$$

It should be noted that in most analytical cases there is no need to make a correction for decimal fractions of a millimetre of pressure and decimal fractions of a degree of temperature: rounding the respective figures, we obtain results of sufficient accuracy. Thus, if we take $P_B = 21.1$ mm Hg, the value corresponding to 23 °C, we would obtain $P_0 = 696.5 \approx 697$ mm Hg. From Table 16,A, for $t = 23$ °C and

$P_0 = 697$ mm Hg we would have $\log F = 92\ 723$, and finally $V_0 = 21.65$ ml, which differs little from the preceding result.

Example 2. What is the weight of 43.7 ml of NO, measured over 28.6% KOH solution at 17 °C and a barometer reading of 757 mm Hg? Suppose the temperature of mercury in the barometer is also 17 °C:

$$P_0 = 757 - \frac{17}{8} - 10.2 \approx 745 \text{ mm Hg}$$

The value of 10.2 mm Hg is found in Table 16,B (17 °C, KOH 28.6%).

The unknown mass is equal to $VF\rho$; we find $\log F$ in Table 16,A, and $\log \rho$ in Table 16,C:

$$\begin{array}{r}
\log V = \log 43.7 = 64\ 048 \\
\log F = 96\ 506 \\
\log \rho = \log 1.3402 = 12\ 717 \\
\hline
\log x = 73\ 271;\ x = 54.0 \text{ mg}
\end{array}$$

Example 3. From 1.200 g of commercial calcium carbide, 395 ml of acetylene (C_2H_2) is obtained at 17.5 °C and $P_t = 755.3$ mm Hg (the pressure is measured at 16 °C). The gas is collected over a saturated NaCl solution. Calculate the percentage of CaC_2 in commercial carbide.

$$P_0 = 755.3 - \frac{16}{8} - 11.4 = 741.9 \text{ mm Hg}$$

The value of 11.4 is found in Table 16,B, interpolating between the numbers 11.0 and 11.7.

The unknown percentage is

$$x = \frac{VFf' \times 100}{g}\ \%$$

The value of F is found in Table 16,A, and f' in Table 16,D.

$$\begin{array}{r}
\log V = \log 395 = 59\ 660 \\
\log F = 96\ 256 \\
\log f' = \log 2.8877 = 46\ 055 \\
1 - \log g = 1 - \log 1200 = 92\ 082 \\
\hline
\log x = 94\ 053;\ x = 87.20\%
\end{array}$$

Example 4. In the reaction of an acid with 0.250 g of zinc dust, 79.6 ml of H_2 is evolved, the latter being measured over water at 20 °C and a pressure of 742 mm Hg (the temperature of mercury in the barometer is also 20 °C). Calculate the Zn content in the zinc dust.

$$P_0 = 742 - \frac{20}{8} - 17.5 = 722 \text{ mm Hg}$$

$$x = \frac{VFf' \cdot 100}{g}\ \%$$

$$\begin{aligned}
\log V = \log 79.6 &= 90\,091 \\
\log F &= 94\,696 \\
\log f' = \log 2.9145 &= 46\,456 \\
1 - \log g = 1 - \log 250 &= 60\,206 \\
\hline
\log x &= 91\,449; \quad x = 82.13 \cong 82.1\%
\end{aligned}$$

The final result must not have more than three significant figures, since only three significant figures contain the results of weighing and volumetric measurement.

In some instruments, gas burettes are calibrated in a way that they directly read the percentage of the substance being determined if the weighed portion is constant (usually 1 g or 0.5 g) and if the gas in the burette is at a definite temperature and pressure. But when the temperature and gas pressure do not coincide with those indicated on the burette, a corresponding recalculation must be made.

Example 5. In determining C in steel by the combustion method in the O_2 current, the volume of CO_2 formed is measured with a gas burette of the Wirtz-Strölein instrument showing the percentage of C when the weighed portion of steel is 1000 g and when the temperature and gas pressure in the burette are 16 °C and 760 mm Hg. A portion of steel weighing 1000 g is taken; the temperature and gas pressure are 20 °C and 740 mm Hg. The burette reading is 0.52% C.

What is the real content of C in steel? In Table 16A, we find $\log F_{760,16\,^\circ\mathrm{C}} = 97\,522$; $\log F_{740,20\,^\circ\mathrm{C}} = 95\,766$. The first logarithm must be subtracted from the logarithm of the percentage of C found, and the second logarithm must be added to it:

$$\begin{aligned}
\log 0.52 &= 71\,600 \\
1 - 97\,522 &= 02\,478 \\
&\ 95\,766 \\
\hline
\log x &= 69\,844; \quad x = 0.49\%
\end{aligned}$$

The difference in the values of vapour pressure over the concentrated alkaline solution at different temperatures is neglected here. If the temperature of the measured gas deviates from 16 °C only by several degrees, the error arising from this is not over 0.01%.

Table 18

Densities and Concentrations of Solutions

In literature dealing with analytical chemistry, concentrations of acids and bases are expressed in different ways: (1) in terms of density (for example: "5 ml of hydrochloric acid with a density of 1.19 is added"); (2) in terms of the dilution of concentrated commercial acids [for example: "10 ml of diluted (1 : 9) sulphuric acid is added to the solution", which means that one volume of concentrated commercial sulphuric acid is diluted with nine volumes of water]; (3) in terms of the percentage of the reagent (for example: "2 ml of 25% ammonia solution") and, finally, (4) in terms of the normality of the solution.

An analyst has therefore to convert the concentrations in calculating reagents used in the reaction on the basis of the solutions whose concentrations are expressed in different ways, and so forth. The conversion tables serve the purpose. It is the easiest to perform stoichiometric calculations if the concentrations of reagents are expressed in their normalities. Therefore, the tables give the normal concentrations of acid and base solutions.

Here are a few examples concerning calculations with these tables.

Example 1. In analysing tin bronze, nitric acid with a density of 1.2 g/cm³ is used to dissolve it. How can the acid be prepared from concentrated commercial nitric acid with a density of 1.4 g/cm³ without the aid of an areometer? The normality of nitric acid with a density of 1.200 is $6.273N$ (Table 18,A); it follows that one litre of it must contain 6.273 g-equiv. The normality of concentrated nitric acid with a density of 1.400 is $14.88N$; one litre of it contains 14.88 g-equiv. The required quantity (6.273) of gram-equivalents of HNO_3 is contained in $\frac{6.273}{14.88} \times 1000 = 421.6$ ml of concentrated nitric acid. Measuring out this volume and diluting it with water to one litre, we obtain nitric acid whose density is 1.2.

Example 2. In the course of an analysis, 5 ml of diluted (1 : 4) HNO_3 are added to a neutral solution and then neutralized with ammonia. How many millilitres of concentrated (25%) ammonia solution will be used in the neutralization reaction?

The expression "diluted (1 : 4) nitric acid" implies that one volume of concentrated nitric acid with a density of 1.400 is diluted with four volumes of water. The normality of concentrated acid with a density of 1.400 is $14.88N$, and that of the diluted acid will apparently be $14.88 : 5 = 2.98N$. Five millilitres of this acid are added to the solution being analysed; to neutralize it, 5 ml of ammonia solution of the same normality ($2.98N$) are apparently necessary. The normality of concentrated 25% ammonia solution is $13.32N$ (Table 18,I). It follows that, to neutralize nitric acid, $\frac{5 \times 2.98}{13.32} = 1.12$ ml of concentrated ammonia solution will be used.

Example 3. A portion of rock weighing 1 g is melted in a platinum crucible with six times as much anhydrous Na_2CO_3. The melt is leached with water and oxidized with diluted (1 : 1) hydrochloric acid. How many millilitres of this acid must be added to completely neutralize Na_2CO_3 without the acid being too excessive?

$$6\text{g of } Na_2CO_3 \text{ contain } \frac{6}{1/2Na_2CO_3} = \frac{6}{52.9945} \text{ g-equiv}$$

or

$$\frac{6000}{52.9945} = 113.23 \text{ mg-equiv}$$

For neutralization, it is necessary to add the same quantity of milligram-equivalents of HCl. The normality of concentrated hydrochloric acid with a density of 1.190 is $12.50N$, and that of diluted (1 : 1) acid is consequently $6.25N$, i.e., 1 ml of the latter contains

6.25 mg-equiv of HCl. It follows that Na_2CO_3 is neutralized by $\frac{113.23}{6.25} = 18.12$ ml of diluted (1 : 1) hydrochloric acid. If 20 ml of the acid are added, it would not be too excessive.

These examples show how much easier it is to perform calculations when concentrations of acids and bases are expressed in their normalities. Table 18 helps convert differently expressed concentrations. The reliability of the table is so great that its data can be used when preparing titrants of acids and alkalies according to density. The titre of the prepared solution must nevertheless be checked by a weighed portion of a parent substance. Here is an example of calculation when a titrating solution is being prepared.

Example 4. To prepare $1N$ HCl titrant, an acid available in the laboratory is taken, its density determined with an areometer is equal to 1.082 g/cm³.

From Table 18,C we have: the acid with a density of 1.080 g/cm³ has a concentration of $4.878N$ and that with a density of 1.085 g/cm³, $5.192N$. By interpolation, we obtain the following normality for a density of 1.082:

$$4.878+\frac{2}{5}\ (5.192-4.878)=4.878+\frac{2}{5}\times 0.314=5.004$$

It follows that one volume of the available acid must be diluted to 5.004 of the volume. For this purpose, we can measure out, for example, 200 ml of the acid with a density of 1.082, pour it into a one-litre volumetric flask, dilute it with water up to the volume and add another 0.8 ml of water (1 : 5.004 = 200 : 1000.8).

Table 19

Chief Acid-Base Indicators

For volumetric-analytical titrations (acidimetry-alkalimetry methods), it is necessary to select indicators that change colour in the pH range as little as possible. Such indicators as azolitmin, which changes colour at pH values from 5.0 to 8.0, are not suitable at all for titration. Of little use are also indicators whose colours of both forms lie in a spectrum too close to one another, for example, indicators which change their colour from red to orange, from orange or orange-red to yellow, from blue-violet to blue, and so forth. In recent years, indicators which sharply change their colours to spectrally opposite ones in very narrow pH limits have been synthesized; for example, nitrazine yellow, which changes its colour from yellow to blue-violet within pH 6.0-7.0, or quinoline blue, which is colourless at pH 7.0 and violet at pH 8.0.

The main rule in selecting an indicator for volumetric-analytical determinations is that *the titration index* pT *of an indicator must be as close as possible to the* pH *of the solution at the end of titration*, i.e., *when the equivalence point is reached.* The titration index pT is the pH at which the observer can clearly see the colour change and recognize titration as complete. This is a conditional value which differs for different persons who perform titration. If the eye could easily detect the slightest change in colour, the pT would obviously coincide with the equivalence point. But since titration is usually completed at visible colour change, it can be assumed that, with dichromatic indicators, the pT is approximately at one-quarter of an interval from its corresponding limit.* With monochromatic indicators (phenolphthalein, nitrophenols), the pT almost coincides with the beginning of the appearance of colour, provided that the indicator is used in the dilution at which its colour change was determined.

For analyses of great accuracy, it is always necessary to separately prepare a buffer solution with a pH which coincides with the pH of the equivalence point and add the indicator to it, and then titrate the solution being analysed until its colour coincides with the colour of the prepared reference solution.

When a weak acid is titrated with caustic soda, at the end of the titration a solution of sodium salt of the acid is formed which, as a result of the hydrolysis of the salt, has an alkaline reaction. Knowing the ionization constant of the acid, the pH of the solution formed can be determined and, in accordance with this pH, a suitable indicator can be selected. This is also true of acid titration of a weak base solution, when a salt is formed which has an acid reaction in the solution as a result of hydrolysis.

In hydrochloric acid titration of a salt solution of an alkali metal and weak acid (for example, Na_2CO_3), the solution will contain, at the end of the titration, neutral chloride of the alkali metal and free weak acid, consequently having an *acid reaction*. Knowing the ionization constant of this acid, we can calculate the pH of its diluted solution obtained at the end of titration and select a suitable indicator.

When a strong acid is titrated with a strong *alkali solution* (or vice versa), a solution of neutral non-hydrolyzing salt with the pH of about 7 is obtained. But there is no need to use an indicator which changes its colour at pH close to 7, since the smallest drop of the titrant sharply displaces the pH to an acid (in acid titration) or an alkaline region (in alkali titration). In such titrations, any indicator can be used; nevertheless, when titration is performed with a greatly diluted solution of acid or alkali (for example, 0.01*N*) whose drop contains a very small amount of the titrant, the indicators showing colour change in the pH range of 5 to 9 should be used.

Table 21

Colorimetric Determination of the pH of Solutions

For the colorimetric determination of the pH of solutions, indicators which change colour within a small pH range are of little use. Most useful are dichromatic indicators which, within a sufficiently large pH range, show noticeable changes in shades when the pH changes by 0.1-0.2. Use is also made of monochromatic indicators whose colour becomes, as the pH changes, more or less intense while retaining shade. In both cases, the colour is determined that the indicator assumes in the test solution and in a set of standard buffer solutions having different pH values preliminarily found by the electrometric method. The pH of the test solution is equal to the pH of the buffer solution whose colour is the closest to that of the test solution.

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* Some analysts believe that the pT is in the middle of the interval of the indicator colour change.

In the colorimetric determination of the pH, account must be taken of the following possible sources of errors which should also be considered when selecting an indicator.

(a) *Influence of foreign salts.* Let us denote the ionization constant of an indicator as K_{Ind}. Then, $K_{\text{Ind}} = \frac{a_{\text{H}^+}a_{\text{I}^-}}{a_{\text{HI}}}$, where a_{I^-} is the activity of the indicator anions formed as a result of dissociation, a_{HI} is the activity of its undissociated part. In the example, the indicator is a weak acid, and if the indicator is a base, further reasonings do not change in the main. Having replaced the activities by the products of concentrations and activity coefficients, we obtain:

$$\frac{[\text{HI}]\,f_0}{[\text{I}^-]\,f_1} = \frac{a_{\text{H}^+}}{K_{\text{Ind}}}$$

where f_0 is the activity coefficient of the coloured or colourless undissociated part of the indicator; f_1 is the activity coefficient of the coloured anion; the corresponding concentrations are in square brackets.

The colour of the solution depends on the ratio $\frac{[\text{HI}]}{[\text{I}^-]}$, and therefore the solutions having the same ratio will have the same colour. But will the solutions having the same ratio $\frac{[\text{HI}]}{[\text{I}^-]}$ have the same pH? Let us present the above expression in the following form:

$$\frac{[\text{HI}]}{[\text{I}^-]} = \frac{a_{\text{H}^+}f_1}{K_{\text{Ind}}f_0}$$

If the solutions have different ionic strength, the values of f_1 will also differ (and, to a very small extent, those of f_0, which can be neglected). With increasing ionic strength of a solution, the activity coefficients of ions decrease and, consequently, so does f_1. When the colour of the solution does not change, i.e., it has the same ratio $\frac{[\text{HI}]}{[\text{I}^-]}$, the value of a_{H^+} must accordingly be greater: the solution will yield the same colour with the indicator, being more acidic. Conversely, with decreasing ionic strength, f_1 increases, and a_{H^+} must accordingly be less when the solution has the same colour. The pH value of buffer solutions is determined electrometrically usually at the ionic strength of 0.1. If the ionic strength of a solution being analysed is greater than 0.1 (owing to the presence of a large amount of salts), the solution will have the colour which corresponds to that of the buffer solution with higher hydrogen-ion concentration (lower pH). Consequently, it is necessary to make a correction which has a negative value in this case. If the ionic strength of a solution being analysed is less than 0.1 (the solution contains a small amount of salts), then with the same colour that the indicator has in the buffer solution, the solution will be less acidic (higher pH) and the correction will have a positive sign. This correction is called *salt correction*. It should be noted that this correction depends *not only* on the ionic strength of a solution, but also on individual properties of the indicator and the nature of ions that are present. If use is made of the indicators whose acidic form is a single-charge anion and whose alkaline form is a double-charge anion (phenolphthalein, sulphophthaleins), the correction will be greater than when use is made of the indicators whose acidic form is an undissociated molecule and its alkaline form is a single-charge anion (mononitrophenols). Dimethylaminoazobenzene-sulphonic acid (methyl orange) and dimethylaminoazobenzene-*o*-carboxylic acid (methyl red) cause a very small salt error owing to their amphoteric nature, and therefore they are mainly used in determining the pH of solutions having a variable content of salts. If the ionic strength of a solution is greater than 0.1, the correction value is considerably influenced by the nature of salt ions (the size of ion radii) in a solution.

(b) *Influence of the buffer capacity of a solution.* Indicators used to determine the pH of solutions are themselves acids or bases, and if the solution being analysed has low buffer capacity (distilled water, solutions of neutral salts in distilled water, solutions of very weak acids or bases, etc.), the indicator can sharply change its pH. If, for example, 0.1 ml of 0.04% methyl red solution is added to 10 ml of distilled water (pH 7), then even this small quantity of the indicator ($K_{\text{ind}} = 1 \times 10^{-5}$) will change the pH of the water from 7.0 to 5.0.

In determining the pH of such low buffer capacity solutions, their pH will not change if we add to the solution being analysed the indicator solution having the same pH. According to Fausette and Acri,* such solutions of indicators are called *isohydric*. It has been proved that the pH of a solution of low buffer capacity does not change even if *any* amount of an isohydric solution of an indicator is added to it. This underlies the method of determining the pH of such solutions. A set of solutions of an indicator having different pH values is prepared and the solution being analysed is added to every one of them. The indicator solution that does not change its colour is isohydric relative to the solution being analysed.

(c) *Protein error.* A number of proteins greatly affect indicators, making the determination of the pH in their presence impossible. The influence of proteins is specific and depends on the nature of the protein and of the indicator. Therefore, in the presence of proteins, the results of the colorimetric determination of the pH cannot be relied on, having to be verified by the electrometric method.

(d) *Other sources of errors.* In the presence of colloids and sometimes of coarser dispersed particles, an indicator can change colour as a result of one of its forms ("acidic" or "alkaline") being sorbed on the surface of particles. The ionization constant of an indicator changes also at the air-liquid interface. This explains the frequently observed phenomenon when, in shaking a solution of an indicator, the colour of the foam being formed sharply differs from the colour of the solution. When the solution contains finely-dispersed particles of another phase, the result of the determination of the pH must be verified by using two different indicators (acidic and basic) or comparing them with the results of the electrometric determination.

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* Ind. Eng. Chem., An. Ed., 2,78 (1930).

Indicators sharply change colour at pH constant if a non-aqueous solvent—alcohol, acetone, etc.—is added to a solution, and also when the temperature changes.

Table 40

Standard Oxidizing Potentials Relative to the Potential of a Standard Hydrogen Electrode at 25 °C

If a plate of noble metal is immersed in a solution which contains an oxidizing agent and the product of its reduction, there will be a difference of potentials between the plate and the solution, which is called the *oxidizing potential of a given system.*

1. For the system

$$\text{oxidizing agent} + ne \rightleftarrows \text{reducing agent}$$

the oxidizing potential relative to the standard hydrogen potential is expressed by the formula

$$E = E^0 + \frac{RT}{nF} \ln \frac{a_{\text{Ox}}}{a_{\text{Red}}}$$

(where R = gas constant, T = absolute temperature of a solution, n = number of electrons which in the given system make the transition from a reducing agent to an oxidizing agent, F = faraday constant = 96,500 coulombs, a_{Ox} and a_{Red} = ion activities of oxidizing and reducing agents in a solution). Having replaced natural logarithms with common logarithms and having substituted all values of constants in the equation, we obtain for t = 25 °C:

$$E = E^0 + \frac{0.0591}{n} \log \frac{a_{\text{Ox}}}{a_{\text{Red}}}$$

If $a_{\text{Ox}} = a_{\text{Red}}$, then $E = E^0$. The standard potential is the potential of the electrode immersed in a solution which contains both forms (oxidized and reduced) *having equal activities.*

2. If an oxidizing agent is reduced with the participation of hydrogen ions

$$\text{Ox} + m\text{H}^+ + ne = \text{Red} + q\text{H}_2\text{O}$$

then

$$E = E^0 + \frac{RT}{nF} \ln \frac{a_{\text{Ox}} a^m_{\text{H}^+}}{a_{\text{Red}}}$$

In this case, the standard potential is the potential of the electrode immersed in a solution containing both forms (oxidized and reduced) *having equal activities*, and also, hydrogen ions *whose activity is equal* *to unity*. This applies, for example, to such systems as

$$MnO_4^- + 8H^+ + 5e \rightleftharpoons Mn^{2+} + 4H_2O$$

or

$$VO_3^- + 4H^+ + e \rightleftharpoons VO^{2+} + 2H_2O$$

3. When the potential between the metal and the solution of its salt is being determined, i.e., of the systems $Me^{n+} + ne \rightleftharpoons Me$ (for example, $Zn^{2+} + 2e \rightleftharpoons Zn$), and the activity of the solid phase is taken as unity, then

$$E = E^0 + \frac{RT}{nF} \ln a_{Me^{n+}}$$

In this case, $E = E^0$, when $a_{Me^{n+}} = 1$. Here, the standard potential is the potential between the metal and the solution of its salt, when the activity of the metal ions equals unity.

4. When one or the two forms (oxidized and reduced) are sparingly soluble solids or complex compounds, the number of ions formed in the solution will be very insignificant. Let us take, for example, the system

$$AgCl + e \rightleftharpoons Ag + Cl^-$$

For it

$$E_{Ag^+,\, Ag} = E^0_{Ag^+,\, Ag} + \frac{RT}{F} \ln a_{Ag^+}$$

The value of a_{Ag^+}, the activity of silver ions in the solution, is very small and depends on the solubility product of silver chloride SP_{AgCl} and on the activity of chloride-ions in the solution:

$$a_{Ag^+} = SP_{AgCl}/a_{Cl^-}$$

If the activity of chloride ions equals unity, the right-hand part of the equation for the potential will assume the form:

$$E^0_{Ag^+,\, Ag} + \frac{RT}{F} \ln SP_{AgCl} = E^{0'}_{AgCl,\, Ag}$$

The quantity $E^{0'}_{AgCl,\, Ag}$ is called the *standard* ("observed") *potential* of AgCl/Ag system. It can be defined as the potential which is formed in the system containing solids or complex compounds in which all ions participating in the process, except *elementary ions that are separated by precipitates or complexes*, have an activity equal to unity.

The aforementioned equation can be used to calculate the solubility products of sparingly soluble substances by the measured values of the oxidizing potentials.

Here is another example of the formation of a complex compound. For the system

$$Ag(CN)_2^- + e \rightleftharpoons Ag + 2CN^-$$

we also have

$$E_{Ag^+,\, Ag} = E^0_{Ag^+,\, Ag} + \frac{RT}{F} \ln a_{Ag^+}$$

The value of a_{Ag^+} depends on the stability of the complex $Ag(CN)_2^-$ and is determined by the dissociation constant $K_{Ag(CN)_2^-} = \frac{a_{Ag^+}a^2_{CN^-}}{a_{Ag(CN)_2^-}}$. If the solution being examined contains free ions CN^- and complex ions $Ag(CN)_2^-$ in concentrations whereby their activities equal unity, then

$$K_{Ag(CN)_2^-} = a_{Ag^+}$$

and

$$E^0_{Ag^+,\,Ag} + \frac{RT}{F}\ln K_{Ag(CN)_2^-} = E^{0\prime}_{Ag(CN)_2^-,\,Ag}$$

Similar formulas are used to find the dissociation constants of complexes by the data of potentiometric determinations. The table gives several such standard ("observed") *potentials of the systems containing precipitates and soluble complex compounds.*

5. If, in the aforementioned oxidation-reduction system, one of the forms is a gaseous substance, the activity of this substance will be determined by gas pressure, and the standard potential of the gas electrode can be defined as the potential of the electrode in which this gas is under a pressure of 1 atm; the ions which are formed when this gas is reduced (or oxidized) have an activity of unity in the solution.

The equation of the potential $E = E^0 + \frac{RT}{nF}\ln\frac{a_{Ox}}{a_{Red}}$ includes ion *activities* of oxidized and reduced forms, and not concentrations. It follows that, when the concentrations of ions of both forms are the same, the values of potentials in two solutions can nevertheless differ if the salt composition of these solutions and the ionic strength related to it are different. The potential of, say, the system $Ce^{4+} + e \rightleftarrows Ce^{3+}$ is

$$E_{Ce^{4+},\,Ce^{3+}} = E^0_{Ce^{4+},\,Ce^{3+}} + \frac{RT}{F}\ln\frac{a_{Ce^{4+}}}{a_{Ce^{3+}}} =$$

$$= E^0_{Ce^{4+},\,Ce^{3+}} + \frac{RT}{F}\ln\frac{[Ce^{4+}]}{[Ce^{3+}]}\frac{f_4}{f_3}$$

where f_4 and f_3 are the activity coefficients of four- and three-charge Ce ions. As the ionic strength of a solution increases, f_4 will decrease considerably faster than f_3 and, consequently, the value of E will drop. This must always be borne in mind when using oxidation potentials in calculations and reasonings connected with various problems of analytical chemistry, where solutions with a high ionic strength are usually used.

The table gives the potentials of various elements having different valence; the potentials of the direct transition from the highest valence to the lowest one (for example, V^V-V^{II}), and several potentials of the stage-by-stage transition (for example, V^V-V^{IV}; V^{IV}-V^{III}; V^{III}-V^{II}). These potentials are interconnected by the so-called *Luther rule* which states that if an element exists in three degrees of valence m, n and p, and $m > n > p$, then:

$$(m-p)\,E^0_{m,\,p}=(m-n)\,E^0_{m,\,n}+(n-p)\,E^0_{n,\,p}$$

where $E^0_{m,\,p}$, $E^0_{m,\,n}$ and $E^0_{n,\,p}$ are the standard potentials of transitions from valence m to valence p, from m to n and from n to p. For example, Fe exists in the form of ions Fe^{3+} (valence of 3) and Fe^{2+} (valence of 2), and in the form of metal (valence of 0). According to Luther's rule

$$3E^0_{Fe^{3+},\,Fe}=E^0_{Fe^{3+},\,Fe^{2+}}+2E^0_{Fe^{2+},\,Fe}$$

A number of potentials which are very difficult or even impossible to determine experimentally were calculated by Luther's formula.

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